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SCIENCE IN SIGNAL CORPS DEVELOPMENT*

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When it became evident that the world was going to war, there was no class in this country that started to mobilize more quickly than the scientists. During twenty-five years in response to technological advances we had revolutionized our habits of eating, transportation, clothing, entertainment, and communications. It was clear that our methods of warfare must be similarly revolutionized; our scientists and engineers were among the first to recognize that this must be so, and offered their services to that end. They asked only that the Armed Forces define the needs for them to supply.

The decision as to how they could best be used was largely a military problem. It was not a problem that could be solved once for all. Even if it were possible to forecast the entire course of a war in advance, it must pass through varying phases wherein the emphasis on the use of science and scientists will shift. Without such foreknowledge the problem becomes much more complex and uncertain.

Every soldier wishes that, when war does come, he could enter it with his arms and equipment fully developed and in full production. Only in a wholly militaristic country, bent on conquest, is this even approximately possible; in a democracy it is entirely out of the question and therefore, when the European war did come in 1939, we started from scratch. This meant that we had to carry on simultaneously all the consecutive steps of technological progress from basic research, through invention and development, to production.

Nowhere has this been more evident than in the Signal Corps, for we are now using, daily, effects that were only hopes five years ago and that we certainly did not then know how to produce. When we have developed a new technique, we must at once find means to combat it if it should be turned against us, as it certainly will be if the war continues long enough, and so research, invention, and development must continue side by side even after our Army is fully equipped.

At the moment our only mission is to win *this* war. Our most fundamental need to that end is scientific brains to carry out every one of the steps from basic research through production, for it is not until the last step has been taken that the first step contributes its share toward the objective.

We can conceive of someone, after the war, drawing a family of curves showing the value to the war effort of research, invention, development, and production in accordance with the epoch of the war at which they were carried on. Such curves would rise successively to their peaks, hold these peaks for a while, and then decline until the first of them, research and invention, assumed negative values, these activities having diverted manpower from others, while their results were achieved too late to be used in the field.

In actuality, however, such graphs would mean little or nothing. In the first place, we have no knowledge as to the time scale. More important, however, is the fact that it may be the last development to come into use which by achieving strategic or tactical surprise wins the decisive battle and ends the war. Timeliness may be of far greater value than extent of use.

Discounting our graphs, however, we can still see that the process from research to production passes through various phases

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and although we cannot state at what instant we pass from one stage to another, we can state that the first phase is now definitely past. We are beyond the point where we merely knew what technological results we wished to accomplish and were supported only by an inner confidence that we could devise and produce the equipment with which to do it. We have reached a stage where we can produce, and are producing, equipment as fast as we can train men to use it. We know, by experience, that our equipment is, in general, as advanced as any in the world. Therefore, a change in emphasis has taken place in our development program. What this change in emphasis means can best be appreciated by a few illustrations of what has been accomplished in the earlier phase. In 1934 the Signal Corps was given by Congress $170,080 for its entire research and development program. This total budget was approximately equal to our present annual expense for friction tape to insulate the splices in our wire. That year it became evident that Hitler was preparing for war, and so in the following year we were given about $42,000 more with which to start advanced electronic development. The increase amounted to about the present unit price for quantity production of one of the pieces of equipment resulting from that development.

Budgets, however, increased explosively after war started in Europe, and by the time it reached us on December 7, 1941, we had a limited number of detection equipments of two types in actual use. Since then many new types of electronic equipment have been developed, some of it for purposes not even conceived before the war, and based on research done and inventions made since the war started. There are records of well over 500 inventions rising out of Signal Corps projects alone which are of major importance because of broad scope or extensive production, without taking account of any whose value remains to be proved. Navy has at least as many more in the same fields and the contributions of our allies and our own industrial laboratories cannot even be estimated until after the war is over and all records become available.

Although there have been spectacular developments in classified electronic items, this has not been at the expense of other components of signal communications equipment. Before the war we had radio communication equipment that seemed, if not entirely adequate, as good as was likely to be forthcoming. Today we are producing different types of radio sets for infantry, artillery, and tank use, inter-plane and plane to ground, for parachute troops and amphibious forces, radio telephone, telegraph, and facsimile, mobile and fixed station, frequency modulated and amplitude modulated. Only one of the radio sets now in production, however, is of prewar design. New tactics and an advancing art have demanded that the others be redesigned or developed from the ground up.

I spoke a moment ago of "extensive use," but we have given these words a new meaning. Our *monthly* receipts of radio equipment are half again as great as the yearly prewar output of the entire industry. For that equipment we are paying, monthly, as much as the entire cost of the Panama Canal. The fixed plant of the Signal Corps' radio system today exceeds greatly the total of such equipment in the world before the war.

Merely to produce such expansion of manufacture was a technological problem of heretofore unparalleled proportions, and research and development had to compete for manpower and materials with those who were undertaking greatly expanded production to new standards of tolerance. While we were having made, monthly, enough telephone wire to encircle the earth ten times, we were confronted with the problem of learning to insulate it with synthetics instead of natural rubber. While expanding the production of quartz crystals 500-fold, we had to develop new types and learn to keep them from aging.

I have said that "we" did these things, but by that I do not mean the Signal Corps but the *team* formed by the scientists and engineers in industry, the universities, the Navy, the NDRC and OSRD, and the Signal Corps, and the role of the latter has been more and more merely to assign the problems for you and your confreres in civilian life to solve.

It is because of such accomplishments as

have been mentioned that I say the first phase has passed. Even if we wished to do so, we could not put the results of new research and development into production at the rate we have been doing in the past three years. The facilities, the materials, and the manpower to do it do not exist. Moreover, for the moment, we have solutions to most of our basic problems.

Not all of them, of course. As yet, I cannot see through a mere six inches of earth to identify a nonmetallic antipersonnel, or antitank, mine. If you would give me the means to do that, you would save untold lives; if you would go further and show me how safely to destroy the mines when detected, you would save thousands more, not only directly but by restoring to our troops the mobility that the mines now curtail.

Or if you would give me a dry cell that would operate at stratosphere temperatures without too great loss of power, or insulation for wire that would not become brittle at like temperatures, you would deserve the gratitude of a nation. Or give me a sound powered telephone with a talking range equal to the externally powered variety. These represent a few of the things that remain in the first phase of development; we have not *a* solution, much less *the* solution to problems such as these.

No contribution that could be made at the moment would be more welcome than a really satisfactory source of power. We are not proud of the fact that our small gas engines weigh twenty to thirty pounds per horsepower, as against four-tenths to six-tenths for aircraft engines. A small engine that would operate satisfactorily on leaded gas, or even a simple method of deleading gas, would help a lot. In all of our power sources, we need improvements beyond mere refinement; improvements in performance running to higher orders of magnitude. You have given such an improvement to us in dry cells for tropical use, but nowhere else in the power field that I can think of.

I might digress to point out here that an improvement in the order of magnitude in any line frequently has an impact that goes beyond its immediate field and affects almost all lines of endeavor. The radio relay has made a saving of that order in manpower for construction and maintenance which may mean that communications can be established where they were impossible before. The tropical dry cell gives us more shipping space and may mean an all-or-nothing difference in maintaining communication when the going is tough. And new orders of magnitude in precision of dimension or of frequency stability have their effect in every field of science. Research and development growing out of this war have given such improvements in several fields.

Apparently minor developments or improvements may create disproportionate and even spectacular results. For instance, before 1941 the smallest radio transmitter, the radiosonde, was highly uncertain in operation—nearly 90 per cent failed. The famous blond-hair moisture unit was then discarded for a plastic device and a tiny ceramic resistor was developed to measure temperature. The resulting radiosonde (costing only $24 complete with balloon, parachute, and temperature, moisture, and pressure units) always worked, as military equipment must. The importance of this is illustrated by the record of an 80 mm. mortar, firing through overcast. A ground wind was blowing at 12 miles per hour. A radiosonde, however, showed that along the trajectory there was a 213-mile wind, which *only* it could have detected. The incredulous artillerymen, reluctantly and under protest, made a correction of 4,000 yards (over 2¼ miles) in their firing data. Closing their eyes, they shudderingly and prayerfully jerked the lanyard and found, to their amazement, that the projectile landed on the target instead of on their own troops.

Returning to the present phase of our program, the role of development is twofold: first, the improvement and refinement of present equipment; and second, the devising of countermeasures.

Improvement may mean many things, but increase in reliability comes first; and performance, increased range, or accuracy, second. Simplification in manufacture or use is desirable to curtail materials, manpower, and training time, but the importance of simplification can be overemphasized. We now have manufacturers who know how to make, and troops who know how to use,

equipment of high precision and complexity. It is less of a task today to teach the manufacture and use of more complex equipment than it was the manufacture and use of relatively simple gear two years ago, and hence if reliability or performance conflict with simplicity, it is simplicity that will be sacrificed.

I have already referred briefly to countermeasures. Our first approach is to combat the techniques we ourselves have developed on the theory that the enemy will use the same ones eventually if not immediately. Our next step is to find means of combating the enemy's deviltries as fast as he produces new ones, and to concoct still newer deviltries of our own for use when he solves those we are using now.

In the present stage of our development program, both as to refinement and countermeasures, field experience is of utmost importance. That experience is gained in two ways. The first is through reports sent to the laboratories by field units, or gathered by liaison personnel sent to the field from the laboratories. Second, and more important, are the laboratory teams operating within the theaters of operations, and the scientific officers attached to the staffs of combat units. Development has thus moved nearer the front, while research has moved back, entirely into the hands of civilian agencies.

Development must maintain its present status with respect to the Signal Corps up to the surrender of the last enemy. We shall never know when it enters on the phase of declining usefulness shown on our hypothetical graphs, and attempts to forecast that phase are too dangerous even to contemplate. We must remember that Hitler thought he had entered the final phase of his war in 1940 and again in 1941. He entered the war with the idea that he could finish it with the same equipment with which he started. He learned better, and he now has large numbers of highly efficient people thinking up unpleasant surprises for us. The enemy may spring those surprises up to the last minute, and up to the last minute we must be ready to counter them. Somehow we must find a way to continue to use our scientific manpower with undiminished effectiveness, for it is our one irreplaceable resource for which there is no substitute. We must maintain our research teams until the last shot is fired and after, for otherwise we may find that what we thought was the last phase was merely a breather before a new and more deadly resumption.

Therefore, even from the superior knowledge of hindsight, we should not assign negative values to research and development in any phase of the war, any more than business can regret after the fact that insurance premiums did not result in payment of claims not made. Moreover, while it is true that we have but a single mission, when the final phase does come, we shall have a new and equally important one—the prevention of the next war. I hope that we have now learned that preparedness is the best preventive, and our unused techniques will be a major contribution toward that end.

If we are wise, therefore, research and development of much the present type will continue. If so, the present partnership between science and the military will not be dissolved, and neither will be completely demobilized. If that plan is followed, we may be able to postpone the "next war" indefinitely.

SENESCENCE AND INDUSTRIAL EFFICIENCY*

II. SPECIFIC PROBLEMS

By EDWARD J. STIEGLITZ

PERSONNEL executives are concerned with developing policies in connection with certain specific aspects of employment of older individuals. These include the problems of selection of new employees, the question of accident hazards in relation to age, the complex field of placement, the emotional hazards of senescence as seen industrially, and last, though by no means least, the critical problems of key personnel.

SELECTION

Policies concerning selection of new employees are rarely static. Wide fluctuations in the labor force available affect the attitude of personnel officers profoundly. Always, there arises the question of balancing risk introduced by lowered physical fitness against exceptional and valued skills. This question occurs far more frequently with older applicants for employment, for it is these men who have developed exceptional skills and who also have lived long enough to have acquired many physical impairments. The significance of defects varies greatly with the occupation. Extensive and immensely valuable studies have demonstrated that even those with severe physical handicaps are safely and profitably employable. That many such will have to be employed is certain, for our returning war casualties have the right to work. Present-day pre-employment physical examinations are quite adequate, in most instances, to insure against placing workers in occupations where their defects render them a hazard to themselves, to other workers, or to the public.

However, there is one serious flaw in present classifications of physical fitness. There is insufficient distinction between static defects and potentially progressive impairments. Fitness implies more than ability to work safely and usefully today; it implies promise of continuing capacity for such work. The man with one eye, with an artificial leg, or minus several fingers presents permanent but stationary defects, the significance of which diminishes with time as he acquires skill in handling himself and in compensating for his handicap. In contrast, early hypertensive disease (high blood pressure) implies no immediate jeopardy or hazard, but does indicate progression of the disorder with persistently increasing impairment of health and efficiency. Contrary to the usual impression, the younger the individual the more rapidly will such disease progress. A moderately severe hypertension in a man of fifty-five constitutes an employment or insurance risk less hazardous than a mild or early instance in a young man of twenty-five or thirty.

ACCIDENT HAZARDS

The question of accident hazards in relation to age can be dismissed quickly. Casualty insurance rates are not affected by employee age. Though the severity rate of accidents increases with age and longer periods are required for repair and recuperation, the frequency rate of disabling accidents falls to such an extent that the two elements effectively cancel each other. Reduction in frequency of accidents is due to many factors, including greater skill, greater caution, lessened horseplay, and greater familiarity with the hazards of the specific occupation. Except in occupations requiring exceptional agility and speed of muscular coordination, senescence can be ignored as contributing appreciably to the accident risk.

PLACEMENT

Placement of senescent employees is a much more complex question. Training and previous experience, skills, and physical fitness are still the basic guides to proper placement. Techniques for determining aptitudes and potential skills have been developed to a fine art. Many organizations now go to great length to insure that new young employees are carefully screened so that each shall be fitted into a niche appropriate to the

* Continued from p. 414 of the preceding issue.

contour of his character and capacity. This is splendid, so far as it goes, but it does not go far enough. For, all too frequently, once the peg is carefully fitted into the proper hole, it is left there and forgotten. As time goes on, the job remains the same but the man does not. He changes with age. As he changes, the fit between man and job often gets worse and worse. Consequently friction arises: friction causes inefficiency in the operation of the human machine as in any other. Work accomplished is reduced and the worker is affected to his detriment by emotional stresses, the origin of which both he and his foreman usually fail to recognize. Resentment and a growing sense of futility soon play havoc with production. Criticism results either in resignation or in escape through development of neurotic complaints of physical ills to account for growing inefficiency. Physical and mental health are inseparable; man is a single, though complex unit. High labor turnover and neuroses are the two nightmares which accelerate the senescence of personnel executives more than any other. Both employer and employee lose; there is much waste here.

Recognition on the part of personnel and supervisory officers that aging brings about changes in men's speed, endurance, outlook, interests, enthusiasms, judgment, muscular strength, visual acuity, and sense of responsibility can do much to reduce the ill effects of bad job placement. If the fit between man and job is to be maintained over the years, then the job must be changed as the man changes. Some will say this is impossible and utopian. But it is not. In this war emergency "in-training" of new employees to equip them to handle new and often complicated jobs has proven brilliantly effective. Is there any reason why modified in-training for new jobs more appropriate to changing capacities cannot be continued for old employees? A small percentage of time can well be spent from 20 to 30 to learn how to tackle tasks more appropriate after 30; in the next decade by preparing for the changes inevitable after 40; and from 40 to 50 preparation for the sixth decade becomes an even wiser investment of time. Nor is there need to stop here.

Such continued education has immense potentialities in all walks of life and all occupations. It will answer one of man's greatest emotional needs and thus release much of his energy, often diverted by frustration, to useful accomplishment. Everyone of us requires some sense of progress, the feeling of at least a little forward motion. Without it the drive of ego gratification vanishes and man becomes an automaton. For work that can be done by an automaton, there are machines that can probably do it better. From the point of view of modern industrial production the greatest difference between man and the machine is that man is versatile, whereas the machine is not. Versatility, permitting the development of multiple skills, is a precious element of our human resources and should be cultivated. The long-standing practice of rotating officers in different tours of duty during peaceful periods reveals the value placed upon versatility by our Army and Navy. Industrial personnel policies have been largely in the opposite direction, toward specialization and, therefore, toward limitation. Specialists are fine, even in medicine, but there must not be too many of them, nor their disciplines too highly refined.

The first and loudest objection which will be raised against this suggestion is that "you can't teach an old dog new tricks." It is invalid because the assertion is utterly false. This erroneous concept has already done immeasurable harm and retarded man's development of man more than any other influence. There are several factors which account for the perpetuation of this vicious notion: it becomes a useful alibi for intellectual indolence in later years; it has been fostered by youth, which proverbially is certain that it "knows it all;" and it has saved from embarrassment many who thought to teach the aging and the aged, for they forgot that in order to teach an old dog, one must know more than the dog! Careful scientific studies of the rate of learning in relation to age have conclusively demonstrated that the depreciation is very minor, once the inertia introduced by this false concept is removed. The rate of learning at eighty is about the same as at twelve, with the peak at twenty-two. Disuse of the faculty of learning depreciates one's ability to learn far more than

age per se. If no effort to learn is made after cessation of formal schooling, the ability quickly atrophies; if the practice of study is continued, it declines very slowly.

Emotional Hazards

Senescence introduces certain psychic and emotional influences into our lives which are significant from the point of view of working efficiency. Emotional equanimity is necessary for the continuance of health. Mental turmoil, particularly if long continued, is an active factor in the causation of many physical disorders. Neither the depressed nor the excited individual can work effectively.

Senescence brings about certain intrinsic changes in personality which occur irrespective of environmental conditions. As we grow older loyalty tends to be strengthened, although it may not be as passionately vociferous as in youth. Our sense of responsibility increases very definitely. The tendency to be distracted by minor and irrelevant occurrences diminishes. A lessening of ebullient spirits diminishes the tendency to indulge in horseplay and practical jokes. With accumulation of experience, judgment improves as the years roll on. All these changes are to the good and are indicative of further maturation. Partially counterbalancing these benefits is a tendency toward increasing fixity of mind. Such rigidity of personality is affected greatly by the habits of the individual in preceding years and is particularly prominent in those who have been required to do the same thing in the same way year after year. As we are all creatures of habit, the rigidity of our habits is determined by the frequency of repetition of an act, whether physical or mental. This tendency accounts for the frequent utterance by the elderly of such comments as, "the good old days," "the old way was just as good," and "these new-fangled notions!" We do not hear such remarks from elderly individuals who have been involved and associated with changing techniques and changing ideas. There is little qualitative change in personalities with aging, but rather intensification and fixation of long-standing characteristics. The talkative salesman becomes more garrulous, the curious research scientist becomes more curious still, the opinionated zealot becomes an intolerably bigoted fanatic, and the tolerant, wise director acquires increasing understanding of personalities.

These are the normal changes that occur in personality with senescence. Industrial employment frequently introduces anxieties which may upset the normal progression of an aging personality. The main factor disturbing the older worker is insecurity arising from uncertainty of employment. This is particularly disturbing to those who for one reason or another are unemployed or are likely to be dismissed after fifty. The difficulty of the older man in obtaining new employment has been so great that this sense of insecurity was quite justified. Social security programs and unemployment insurance do not solve the problem of maintaining emotional equanimity. All of us need something more than merely monetary return from work; there is an urgent, though often subconscious, need to feel useful.

Boredom and monotony are dangerous to good mental hygiene. Boredom may affect people of any age. But its consequences are more insidious and progressive in older individuals than in young people. Boredom is less a problem of employment than it is of unwise utilization of leisure.

Another hazard to emotional balance is inadequate promotion. Lack of promotion may be entirely justified because of the work record of an individual but it is just as disturbing to him as if it were a true injustice. He feels that he is being left behind, becomes excessively conservative and increasingly jealous of his years of service. It is against human nature to expect more than a very few individuals to admit that failure to be promoted is due to their own inadequacy. Particularly hazardous are anniversaries of employment, such as occur at ten years or twenty years of service. These make for introspection and dissatisfaction with the personal progress accomplished. Wise counseling, encouragement at just the right moment, and recognition of service by some appropriate celebration or symbol are of great value in diminishing this emotional hazard.

Less frequent but much more dangerous and expensive to Industry is the emotional hazard arising from excessive promotion.

Every individual has definite limitations, a ceiling to his capacity to carry responsibility as well as to do physical work. Not infrequently a man may rise from the ranks and reach the ceiling of his intellectual capacity rather early in life; perhaps in the early forties. Promotion beyond this point creates intense anxiety-states and quite possibly severe and disabling neuroses. A common problem of this type arises in the shop where an unusually able mechanic is made foreman and thus abruptly given the responsibility of controlling men instead of machines. Such a task may be beyond his capacity; subconsciously he recognizes that he is having increasing difficulties and is failing in his new responsibilities, which he was once so proud to accept. Several courses are open to him to bolster his ego and protect him from the pain of admitting failure. He may begin to shout and to bully, he may develop some physical complaints which excuse his inadequacy to himself, or he may become downright unhappy without knowing why. This type of situation interferes greatly with production, if it is often repeated. It is even more common to see such emotional conflicts in personnel doing intellectual rather than physical work. The executive in a position too big for him endangers both his own health and that of the business. Though demotion to work more nearly within the individual's capacity is the obvious treatment, it must be carried out with infinite tact if serious emotional crack-ups are to be avoided.

Another source of emotional turmoil that may make difficulties for the senescent worker is the climacteric or change of life. As a rule this period is more upsetting and difficult for women than for men, but we must not forget that it occurs in modified form also in the latter. The masculine climacteric is often sadly misinterpreted by supervisors with the result that the disturbance is decidedly aggravated. In the male we are more likely to observe difficulty in manual than in intellectual workers, perhaps because of the mistaken notion that virility and sexual vigor are an index to health and physical strength. These cases require wise psychiatric handling and should be studied by the medical service of Industry before disciplinary action or supervisory criticism is offered.

The last major emotional hazard associated with industrial health is that connected with obligatory retirement. At first glance it would appear that this need not concern those interested in maintaining work efficiency, because after retirement work efficiency no longer is of interest to the employer. But a little thought will show that anticipation of inevitable retirement induces turmoil long before it becomes an actuality. Rigid rules requiring retirement at certain chronologic ages accentuate this. As we have previously suggested, it is stupid to use chronologic age as the sole criterion in determining the wise time for retirement. To do so produces a double source of waste. It makes almost obligatory the retention of many men who have become senile prematurely and therefore functionally ineffective and it also wastes the productiveness and valuable services of many men in whom senescence is slower. It would be hard to judge which of these forms of waste is the greater. Certainly the retention of deadwood in positions of responsibility, or where imagination and initiative are valuable attributes, can be a very serious matter. Employees occupied with purely routine tasks are less detrimental to production when retained too long.

From the point of view of the individual, premature retirement while still vigorous, ambitious, and anxious to serve, can be a major disaster. It is an old axiom of clinical medicine that forcing the "one-track-mind" executive to retire is tantamount to signing his death certificate within the year. Unless there is definite and deliberate preparation for the constructive utilization of the sudden leisure, the acute boredom may be deadly. It is sad but true that it is often the men with the greatest drive and unity of purpose who are prone to break under these circumstances. Only lazy men or those who have multiple constructive interests welcome retirement.

Correction of the error of basing retirement on the arbitrary figure of chronologic age is relatively simple. Instead of absolute uniformity there can be variability, based upon highly individualized medical, including psychiatric, evaluation of each individual's fitness to continue in employment on a

specific assignment. Such evaluations must be extremely thorough and cannot be routinized or carried out in a production-line manner. The medical recommendations should be correlated with the strains, responsibilities, and hazards of the individual job. In most instances complete retirement will not be necessary. We should apply the principle that job assignment should be made to fit the man as he changes with age. Senescence is gradual; even more gradual than growth at the other end of the life span. Biologic changes, other than those of disease, are never abrupt. It is truly absurd to say that a man of 64 years and 364 days is capable of doing a responsible and important job and that 24 hours later he is "too old to work."

Key Personnel

Senescence of key personnel poses the most important questions of all those considered here. By key personnel we mean all those men who by reason of knowledge, experience, or skills are difficult to replace. Such men are almost invariably senescent individuals. Wisdom and judgment are conditioned by experience and knowledge which it takes time to acquire. Key personnel include executives, scientists, engineers, and designers. The greater the specialization, the more difficulty will be encountered in replacing such men. Per unit, key personnel are immensely valuable. Their value to Industry is reflected in the grave and heavy responsibilities assigned to them. This extra burden of responsibility obviously makes for additional wear and tear and thus places the most precious units in particular jeopardy. It is good business to insure valuable and productive tools against damage as well as against loss.

Therefore, health maintenance of these men is an integral and essential part of industrial medicine. By health maintenance we imply maintenance of work efficiency. The primary objective is not personal assistance. The job is, and should be, more important than the man. The idea of seeking medical guidance and reporting minor, but possibly significant, symptoms is often pathetically abhorrent to the rugged individualists who are the men that really count. They frequently resent the idea that their health is anybody's concern but their own. Nevertheless, their health and efficiency are the concern of personnel management in the same sense that the efficiency of a fleet of trucks or a battery of expensive and complicated machines is part of plant maintenance. We do not grease our cars and have them overhauled periodically because we feel any particular love for them, but because we want to get as many miles as possible without expensive breakdowns. Though the "tired business man" has been the butt of many jokes, it is no joke that his weariness impairs his efficiency. Brain power is the most precious part of man power. Because of these and other reasons we maintain that attack on the problems of senescence in relation to industrial efficiency should start at the top.

Health is always relative; never absolute. There is always room for improvement. We have outgrown the old definition of health, which stated that health was the absence of disease. This definition is far too limited. Perfect health is an abstract and unobtainable ideal. Health has quantitative attributes involving reserve capacities both in the physical and mental aspects of life. The old definition of health paralleled what statisticians call the mean or average normal. The new concept suggests an optimum state.

The function of medical care under the old definition of health was primarily to cure or alleviate disease. With the broadening viewpoint of what constitutes health, there is an equivalent broadening of the objectives of medical practice. The alleviation of disease might be likened unto the reconstruction of health. When we realize that health is always relative, we can immediately appreciate the possibility for improvement in the apparently well but actually only partially healthy individual. For this type of medicine we have suggested the term *constructive medicine*. The objective of constructive medicine is to bring the level of individual health as close to the optimum as possible.

Obviously, the prerequisite to improvement to any state of relative health is an analysis of the present status. The keystone of the bridge to greater vigor and effectiveness is the periodic health inventory and its bridgeheads are thoroughness and individualization. The choice of the term "inventory" is intentional because so many have abused

and limited the meaning of the phrase, "periodic examination." Health inventory includes as essential elements study of the past history of the individual (it must be remembered that we are today because of what we went through yesterday), a clinical physical examination, certain laboratory and x-ray studies, and investigations into certain functional reserves. Not until all these data are available can a usefully accurate appraisal be made of the state of health or the approximate physiologic age. No business man expects an inventory or annual audit of the state of his business to be accomplished in a few minutes. Nevertheless, it is all too frequent that senescent individuals laboring under great stress and tension will ask the doctor, "Listen to my heart, Doc, and tell me how I am today." This cannot be done.

Reserve capacities to carry increased loads are very difficult to measure unless one creates conditions of stress. We cannot judge the reserve capacity of an automobile motor by listening to it idling at the curb. Driving the car up a steep hill will reveal the reserve power. The situation with respect to the biologic capacities of man is quite parallel. Ordinary examination of the heart does not reveal its capacity to take on a burden of violent effort.

The principle of periodic physical examinations has fallen into disrepute in many quarters, not because of any weakness of the principle but because of poor application. Inadequacy of the examination was mentioned above. A second and frequent fault is failure to apply the information elicited. All too often the findings are merely recorded on a card and filed away. The value of periodic health inventories depends almost wholly upon the soundness and practicability of the advice offered. Individualization of diagnostic procedures and of guidance is essential, particularly in dealing with senescent individuals.

Specifically, periodic health inventories should include consideration of the following possible aids to greater health and enhanced work efficiency: analysis of capacities can reveal the limits of exertion or mental strain beyond which it is unwise to go; discovery of correctable defects in their incipiency makes possible correction before irreparable damage results; early discovery of chronic and progressive disorders, such as diabetes, hypertension, or arthritis, makes possible the institution of medical management to retard the progression of the disease; and it is an opportunity for education in personal hygiene, particularly in such matters as diet, fluid intake, play, adequacy of rest, and emotional conflicts.

Constructive medicine as applied through such periodic consultations is not a panacea which can prevent all ills, nor is it without certain definite and serious limitations. One cannot prevent all disease, any more than safety programs prevent all accidents. Even though a man may be in excellent physical condition, he may still acquire serious and acute illness, such as pneumonia or influenza, or he may meet with a serious accident. But if the individual is in the full bloom of really good health *prior* to the acute infection or accident, his chances of recovery and his speed of recovery are greatly enhanced. One of the fundamental principles of geriatric medicine, which is concerned with the care of the aging, is that in older individuals the outlook in an acute illness is predicated more upon the condition of the patient prior to the acute disorder than upon what treatment is applied. This is just opposite to the situation which applies to illness in youth. The pediatrician has every right to assume that the child was quite healthy prior to an acute illness. The margin of safety gets less and less as we age. Thus constructive medicine, even though it does not prevent all illness, decidedly reduces the total of absenteeism: by shortening the periods of time lost in unavoidable illness; by retarding progressive disorders common in senescence and responsible for frequently recurrent absenteeism; and by actually avoiding certain disorders.

Of perhaps even greater moment are the potentialities of constructive medicine in increasing work efficiency. Improvement of health improves vigor, endurance, and the ability to accomplish. Let us take for example the effects of a mild anemia discovered in the course of a periodic inventory and not associated with any particular complaints on the part of the patient. The consequences of such an anemia can be likened to attempting

to operate an automobile with low grade gasoline as fuel. The car runs, but it does not have the pickup and horsepower that it should and would have if operated with high octane gasoline. Correction of such minor anemias has precisely the same effect upon the work capacity and pleasure in life of individuals who are just slightly below par. For a long time I have wished for the opportunity to measure the productive output of perhaps two hundred workers, before and after the correction of anemias so apparently minor that most physicians ignore them. The range between average (normal) and optimum is considerable. Examples of this nature could be multiplied indefinitely.

The chief limitations of periodic consultations for the improvement of health are the time and cost involved in carrying them out correctly. Yet, if done at all, the inventories *must* be comprehensive and detailed or the procedure will again fall into disrepute because of slipshod, hurried, or routinized application. That time and money so spent are wisely invested has been proven repeatedly.

Partly because of the inevitable expense per unit so serviced, constructive medicine of this type should be applied first to the key men in Industry. The value of these individuals is such that the cost is proportionately negligible. It is wasteful to permit the physically exhausted individual, who is running on his nerve and likely to crack at any moment, to continue in a directive capacity. Just as it is the Flight Surgeon's assigned responsibility to ground pilots when not fit to fly, it should be the responsibility of Industry's medical advisors to "ground" key personnel when unfit to carry on. Furthermore, the application of a thorough physical and mental inventory should start at the top because Labor has always been opposed to periodic examinations. Such is the childishness of mankind that if this be offered to Management and not to Labor, it will not be long before Labor will clamor for it.

For proper application it is essential that the medical inventory be completely confidential. It is impossible to obtain honest and complete histories from individuals who suspect that the record of their examination will be made available to their administrative superior or to anyone else outside of the physician's office. These inventories frequently include much very personal material, and full intimacy between the patient and physician is requisite. The greater the confidence of the patient in the integrity, as well as in the clinical skill, of the physician, the greater the possibility of benefit. Furthermore, the administrative superior or lay personnel officer is in no position to evaluate the significance of the medical findings. It must also be emphasized again that the detection of minor but potentially significant disturbances and early depreciations of reserves requires the highest type of diagnostic acumen. Therefore, it may often be best to arrange periodic consultations outside of the plant medical department and to have merely a report of recommendations returned to the administrative head.

THE UNITY OF SCIENCE IN EDUCATION

By CHARLES I. GLICKSBERG

IT requires no extensive documentation to support the thesis that the modern mind has been decisively influenced by the growth and development of science—whether for good or evil is in this connection beside the point. The spread of scientific enlightenment has been going on for centuries; what is novel about our age is the extent to which the scientific outlook has been diffused so that our philosophy of life has been radically transformed. To acknowledge this fact need imply no excessive faith in the potentialities of science. The laws of physics may not be the laws of fate; scientific thought may perhaps be guilty of injecting an unconscious quasi-theological absolutism into its interpretation of the universe; scientific materialism may have its serious limitations as a philosophy. But these criticisms, and many others like them, do not impede the steady advance of science. On the contrary, paradoxical as that may seem, they hasten its progress. For the health of science depends on systematic and rigorous self-criticism. It is more than willing to meet the challenge of competing systems of thought if these can prove the empirical validity of their argument. If they succeed in doing so, they are simply incorporated into the revised body of scientific thought.

But in its reliance on controlled observation, science makes no concession to the apostles of obscurantism. Inherent in the scientific method is a faith in reason which it is clearly the duty of the schools to convey. What is this faith in reason? It has been admirably stated by Alfred North Whitehead in *Science and the Modern World:*

> [It is] the trust that the ultimate nature of things lie together in a harmony which excludes mere arbitrariness. It is the faith that at the base of things we shall not find mere arbitrary mystery. The faith in the order of nature which has made possible the growth of science is a particular example of a deeper faith. This faith cannot be justified by any inductive generalization. It springs from direct inspection of the nature of things as disclosed in our immediate present experience.

If modern education is to be maximally effective, it must strive to implant in the mind of the young the realization that the scientific method has universal, not limited, validity. It is not restricted to the observations or insights of any one group of individuals; it is not confined to "material" things or to specialized subject matter; it embraces within its scope all problems that men must face, all that is given, the mental as well as the physical, the social as well as the narrowly "scientific." It can be, though of course with varying degrees of precision and fruitfulness, applied to all fields of inquiry. Hence educators must throw off the departmentalized frame of mind and form a new and more inclusive perspective which will reveal and help to put into practice the unity of science in the educative process. As Karl Pearson challengingly stated the issue in his *Grammar of Science* about thirty years ago: "The field of science is unlimited; its material is endless, every group of natural phenomena, every phase of social life, every stage of past or present development is material for science." The truth Karl Pearson formulated has not been adequately grasped and its experimental application in the schools has scarcely been attempted.

If the schools have thus far failed miserably in their efforts to train students in scientific habits of thought, the scientist as well as the educator must be held blameworthy. It took the scientist a long time to realize that he could no longer remain "pure." Inevitably the centripetal pull of society draws him into its vortex and forces him to participate in its activity. He can no longer isolate himself on the ground that his work is devoted to "pure" research or to "pure" science. Increasingly he has been compelled to assume social responsibility for the consequences of his experiments, his discoveries, and his teaching. This growing sense of social responsibility is specially marked in the writings of men like Hyman Levy, J. D. Bernal, Lancelot Hogben, J. G. Crowther, John Dewey, and Alfred Korzybski. Nor

is it surprising to find that they emphasize the importance of education as one means of changing the mind of man and eventually transforming social practice.

Unfortunately many scientists are still bogged down in the rut of the traditional distinction between science as method and science as "life." Equally unfortunate is the fact that the public is held captive by the same stereotyped dualism. It is commonly believed that when the scientist puts on his laboratory coat (like a priest donning his sacerdotal vestments) and looks through a microscope, he is behaving scientifically. As soon as he doffs his coat, he reverts to type; that is, he is privileged to think and behave according to other than scientific canons. This is the popular religion of science based on a profound misconception of the function and sphere of scientific thought. It springs from a failure to comprehend the indivisible unity of science. People generally manifest an almost worshipful attitude toward the scientist. They regard him as a holy oracle, a final authority, one who knows all the answers. The modern equivalent of the primitive shaman, he peers into the inner mysteries of Nature, he weighs the sun and measures the parallax of a star, he searches for the cure of cancer, he brings the dead back to life.

By thus erecting science into a virtual religion, people unconsciously but effectually separate it from life—the life they lead from day to day. When there is something wrong with their heart or digestive tract, they immediately consult a doctor; when there is something wrong with the body politic, they will often turn to the demagogue or the dictator for a magical solution. What is even more striking, in matters social, economic, and psychological, regardless of how complex these may be, they believe themselves perfectly qualified to pass judgment. They have no hesitation, for example, in venturing reckless, unsubstantiated opinions on the subject of race, international peace, the treatment of the Germans after they have been conquered, the intrinsic inferiority of the female of the species as compared to the male, the sinfulness of divorce, the nature of intelligence, and the inheritance of acquired characteristics.

The same harmful dichotomy is also evident in the traditional teaching of science. Physics and chemistry and biology and general science are taught primarily for their value as subject matter: so many blocked out chunks of knowledge to be handed out to each student. It is doubtful if there is much of a carry-over from the lessons assigned and taught from the textbook, often by the outmoded lecture or demonstration method, to the problems and perplexities that the students encounter in their everyday life. How could there be when, with few but notable exceptions in some progressive schools, no explicit effort is made to apply scientific knowledge to the vital stuff of experience? In one classroom, the students hear of the "law" of gravity and the "laws" of motion; in the next, they engage in furious but unilluminating debates on the problem of equal rights for women, racial tolerance, war, democracy, Communism, Fascism, and world peace. Any one listening to them "think out" these problems in class will observe the ease and readiness with which they indulge in "phoney" catchwords, the uncritical aggressiveness with which they make statements unsupported by a shred of evidence, the ardor with which they voice beliefs that have no empirical foundation. They use symbols which point to no clearly given occurrent because they are driven primarily by the desire to dominate, the will to win the argument. There has apparently been no transfer value in the scientific instruction they have received. Not that the science teacher is alone to blame. Every teacher must bear his share of the guilt. The science teacher tries to do a conscientious job, but his method of approach is wrong. The uncritical thinking of the students we turn out is a sufficient indictment of our educational system as it functions at present. The gap between science as theory and science as conduct, science as "laws" in textbooks and science as living thought applied to all human problems, has not been bridged, and the gap yawns widest in our schools.

The relationship between democracy and a genuinely scientific education is closer and more important than we commonly realize. In a democratic state, no distinction is drawn politically between those who use their intelligence critically and those who fail to do so,

between those who utilize their knowledge constructively in order to improve themselves and to contribute their maximal share to the progress of society and those who walk in darkness. The vote of the ignorant hill-billy counts as much in electing a man to Congress as that of the professor of sociology at the State University. Yet all these people are the concern of the educator. A democracy must endeavor, by means of its educational resources, to combat the influence of unscientific thought and action. It must furnish a basic scientific education to all people so that they may be better informed, more discerning in their judgment of affairs, more intelligent and discriminating in their actions. Since the educational goal should be to make scientific thinking function in all areas of living, all teachers have a responsible role to play in improving the power of the young to think critically. It is essential that they be taught in a way to make scientific habits of thought habitual and enduring.

This is but another way of saying that departmentalized instruction, which attempts to feed students knowledge regardless of their interests or needs, is ineffectual. Nothing is more potent in one's own education than his factually-founded realization of the inexorable nature of scientific occurrences. The laws of science give him true freedom; he can depend on them as he can on nothing else in this precarious universe.

It is in the schools that the battle of science will be fought—and lost or won. Despite all the magnificent progress being made in the field of war technology, the net result, so far as its effect on the thought and behavior of the masses of men and the management of society is concerned, is negligible, and will probably continue to be negligible unless education specifically takes over the task. Either science is useful and valid in solving our crucial human and social problems or else it is but a specialized discipline applicable within certain circumscribed areas of experience but not relevant to the total complexity of human life on this spinning planet. If we adopt the former alternative, then we shall not agree with those thinkers who argue that science is, by definition, cut off from the realm of values. It is, they maintain, descriptive, not normative. It tells us *how* things happen; it can cast no light on *why* they happen. Here we reach to the root of the philosophical problem, the heart of science. The solution we give to this problem will determine in large measure the kind of scientific education we provide for the young. What ultimate purpose life on earth serves, no one knows, and it does not appear likely that we shall ever find out. How the universe may appear to a creature endowed with a different sensory apparatus, finer, more complexly differentiated than ours, is beyond our scope of knowledge. Even at the risk of tautology we must repeat: we can know only that which we can know. The rest is silence. Our brain, our senses, our perceptions, our reason, these working organismically furnish us with the material out of which public knowledge is born, and this empirico-rational knowledge is our sole reliable means of mastering our environment and of controlling our life, individually and collectively. There are those who profess to have access to supernatural or intuitive sources of knowledge, but since there is no way of empirically confirming that which they know, their "knowledge" must be rejected out of hand as not belonging within the scientific canon of tested knowledge.

If this thesis be accepted, then it logically follows that scientific habits of thought, like socially acceptable behavior, are the province not of one department but of the school as a whole. It is the basis and superstructure, the seed and flower, the crown and consummation of the educative process. Hence it is the function—nay, the bounden duty—of every teacher, though with varying degrees of thoroughness and skill, to train and develop the young in the "art" of scientific thinking. Teachers of all subjects should not only be scientifically literate; they should welcome every opportunity of cooperating with science teachers so that the ultimate aims of education may be most efficiently and fruitfully achieved. Teachers of English, for example, are dedicated to the task of bringing beauty into the life of students, but there is no convincing reason why the quest for beauty should not be strengthened and supplemented by the quest

for truth. The two are not, as is commonly believed, in conflict.

Once the departmental barriers are broken down and the bigotry and provincialism that are the product of departmentalization have been dissipated, it should be relatively easy to devise ways and means of putting into practice the ideal described above. The English teacher, to use him again as an example, has at his disposal a rich variety of material from which to choose, though there is no teacher, no matter what his subject, who cannot play his part in the attack on prejudice, muddled thinking, lazy intellectual habits—the idols of the market place. Discussions alone will not remove deep-seated emotional prejudices or extirpate the roots of bias, but they can throw light on dark places and gradually compel students, still open to the voice of reason, to re-examine the basis for their hasty yet cocksure assumptions.

In addition to the teaching of subjects like physics and chemistry, it is essential that the young receive thorough training in the science of "human nature." Such a course, which is fundamental to practically every part of the curriculum, would be as comprehensive in scope and detailed in procedure as the interests and abilities of the students permit. Like all those who have no professional scientific knowledge or training, what the young are primarily concerned about is how human nature functions, why we behave as we do, the secret of the mind and body and their interaction. What they seek is not only information about stimulus-and-response, conditioning, heredity, the influence of environment, and so on, but also insight into the way scientific methods of control can "change" and "improve" human nature. It is scarcely an exaggeration to say that if we could arrive at an objective and empirically tested agreement on the nature of what we call "human nature," half the controversies that now rage in the field of politics, sociology, economics, and philosophy would automatically end.

To be successful, such a course would have to deal with problems that challenge the interest of the young. History teachers, English teachers, and science teachers could join forces in helping students to undertake simple research in some such problems as: What is intelligence? Is there a close correlation between intelligence and race? Is character the result of heredity and environment, or both, and in what proportions? What characteristics are inherited and what acquired? Why do many people act irrationally? How does the human mind work? What is hypnotism? Are people highly suggestible? How is this used by business and political interests to influence the minds of men? Is mental telepathy scientifically confirmed? Is it possible to foretell the future? Many of these problems no doubt will prove highly difficult, perhaps insoluble, but it is a profitable experience for the young to tackle them even if in the end they feel baffled. For that is a good way of putting the scientific method actually to work and testing its range of operational validity. Once the student comprehends how the scientific method is applied, he will discover in the course of his investigations the difference between relatively certain truths and those truths which possess only a weighted measure of probability. All the facts can never be gathered. Hypotheses are not absolutely certain. That is the best we can attain in this contingent and hazardous universe where risks must always be taken. Even facts are elusive, subject to change and correction. When incontestable evidence is lacking, however, there is no reason for falling back on childhood faith or wishful thinking. Students are under a moral obligation, whatever the problem they are exploring, to weigh all the available evidence and arrive at the best possible conclusions under the circumstances.

Recently there have been published books which are within the range of comprehension of high-school students. *Life and Growth,* by Alice V. Keliher, one of the volumes issued by the Commission on Human Relations, is interestingly written, easy to understand, and challenging in content. Also excellent as an introduction to scientific thinking is Paul Grabbe's *We Call It Human Nature,* with cartoons illustrating the fundamental subject matter of psychology and textual material describing the basis for psychological insight into the complexities of human nature. Students interested in the study of

superstitions should read *Do You Believe It?*, by Otis W. Caldwell and Gerhard E. Lundeen, and then proceed to gather field material from their own communities.

No doubt there will be science teachers who will look disparagingly upon this curricular innovation as but another step in the direction of popularizing and vulgarizing science. Diluting scientific knowledge, dramatizing it so that it will hold the interest and penetrate the intelligence of the average adolescent is in their eyes a form of treason. But they are mistaken. The issue is one between effective teaching that leaves its indelible stamp on thought and conduct, and ineffective teaching, knowledge that remains theoretical, abstract, unassimilated. The traditional science course in high schools leaves those students who have neither the opportunity nor the ability to enter college with an utterly inadequate conception of the scientific method and outlook in our society. Even if in their class they were told of the enormous importance of science in our civilization, the breach between theory and practice, science and life, would still not be closed. If science is to be more than an honored part of the curriculum, if it is to be more than a quantitative inculcation of subject matter, if it is to permeate the personality and condition the mind of the student so that he will think more critically and behave more rationally, then it must be taught as such. All science teaching, particularly on the secondary school level, must be "impure," applied, humanly practical and significant. It should be concerned not only with machines, amperes, atoms, motion, light, heat, electricity, and chemical formulas; its scope is the entire universe, all of human life.

It includes such unorthodox and relatively unexplored subjects as economics, politics, human nature, love, hate, war, dreams, myths, religions, attitudes, opinions, beliefs, values, truths. All these fall within the spacious province of science. What differentiates them from "science" proper, in the conventional sense of the term, is that the degree of probable truth to which we can attain in the social and psychological sciences is less precise than what we can hope to achieve in the physical sciences, but the scientific method of attacking a problem and arriving at provisional truths remains unchanged. If the obscurely given is to be known, it can be known only through the aid of the clearly given, that which is already known. If science is to justify itself and prove socially useful, it must break down the artificial barriers, departmental and falsely humanistic, erected with the design of limiting its function and scope. Everything points at present to the imperative need for a drastic revaluation of educational objectives. As John Dewey summed up the matter in 1933:

> The obligation incumbent upon science can not be met until its representatives cease to be content with having a multiplicity of courses in various sciences represented in the schools, and devote even more energy than was spent in getting a place for science in the curriculum, to seeing to it that the sciences which are taught are themselves more concerned about creating a certain mental attitude than they are about purveying a fixed body of information or about preparing a small number of persons for the further specialized pursuit of some particular science.

TREES OF SOUTH FLORIDA

I. FIVE NATURALIZED EXOTIC FOREST TREES

By JOHN C. GIFFORD

WHEN Florida's winter visitors think of trees, they probably visualize her palms, not knowing, or forgetting, that other unusual and useful exotic and native trees grow in South Florida. It is the purpose of this article to call attention to ten kinds of trees that could be grown profitably on many thousands of acres now idle.

THE CANDLENUT TREE

The candlenut tree (*Aleurites moluccana*) is a near relative of the better-known tung tree (*Aleurites fordii*), which has been planted in the Gulf States to furnish a domestic source of tung oil. Candlenut oil is also a valuable drying oil, which is acknowledged to be as good as the best grade of linseed oil and with proper treatment serves well for several of the purposes for which tung oil is used. It is strange, indeed, that the candlenut, which grows so luxuriantly and fruits so freely in South Florida and the West Indies should be neglected, because the tung tree, not as good silviculturally in the United States, produces a somewhat better oil. Since the supply of tung oil from the Orient has been cut off by war, it would seem wise to develop all sources of drying oils, not only tung oil in the Gulf States and oiticica oil in Brazil, but also candlenut oil in Florida

In contrast to the tung tree, which is a deciduous tree of temperate climates and grows relatively slowly, the candlenut tree grows with great rapidity in South Florida, producing an enormous crop in less than ten

A CANDLENUT TREE

IT IS SO LOADED WITH FRUIT THAT THE LIMBS ARE BENT BY THE WEIGHT OF THE LARGE NUTS.

years, during which period many trees will become a foot in diameter. Whereas the tung tree requires good agricultural land and much attention to cultivation and fertilization, the candlenut can be grown as a forest crop on the inexpensive, rocky limestone land of South Florida.

The natives of the South Sea Islands string the nuts on a stick and use them in place of candles—hence the name. The candlenut is a common tree in the Hawaiian Islands, where it is called *kukui* by the natives, who have long extracted and used the oil from its nuts.

Three additional tropical species of *Aleurites* are *trisperma*, *cordata*, and *montana*. The word *Aleurites* means flour in Greek and was chosen for the genus because the young leaves look as if they had been covered with meal. The nut of *A. trisperma,* the nu-oil tree, is soft and not difficult to press, but the few trees of this species in South Florida, although fruitful, are not very thrifty.

The Sapodilla

Industry in Yucatán is devoted mainly to archaeology and chewing gum. The latter is the gum of the sapodilla tree. In addition, this tree yields a wholesome fruit, which, Barrett says, is equal to a good pear sprinkled with spices and flavored with maple sugar. The fruit resembles rusty-coated apples. When green, it is full of sticky gum which soon ripens into a sweet, palatable juice. The Conch of the Florida Keys talks feelingly of his "sours and dillies." By sours he means limes; by dillies the sapodillas, sapodilla being the Spanish for little *sapote.*

The great home of the sapodilla is the Yucatán Peninsula. The ancient Mayas used its wood for timbers in their buildings, and it has lasted for centuries, being more durable than metal. They are said also to have chewed its gum. The present gum gatherers cut the trunk of the tree with a machete in V-shaped gashes. The milk flows into a hole at the foot of the tree, or on broad leaves or a canvas sack. The trees are allowed to rest from four to seven years, but now and then a large number die. The principles of forestry are beginning to be applied to growing sapodilla in British Honduras where, it is hoped, "supplies from fully stocked crops of sapodilla established by silvicultural methods will supersede the gum derived from the wild collecting industry." I could never understand why the gummy milk could not be squeezed out of the green fruits and thus obviate the necessity of mutilating the tree to death.

The sapodilla has been growing in South Florida, especially on the Keys, for many years. It was probably introduced here from the West Indies or Central America. Some assert that it is native, but it is probably a naturalized species.

The Lebbek Tree

The scientific name of the lebbek, or siris, tree is *Albizzia lebbek*. A sister of this tree, *Albizzia julibrissin,* is common in the South as far north as Washington. Albizzi, for whom the tree was named, was an Italian nobleman, who was among the first to plant seeds of this tree in Italy. The specific name *lebbek* is, perhaps, of Arabic origin. My first interest in the tree began by reading David Fairchild's Circular No. 23, Division of Botany, U. S. Dept. of Agriculture, in 1900. He says, "The sapwood is white and heartwood hard, brown, mottled with darker longitudinal streaks. The wood seasons and works well and is durable." He notes that hundreds of thousands of these trees were planted in Egypt in 1809. He says further that it is "as easily transplanted and propagated by cuttings as a willow. Large trees can be dug up, severely pruned back and set out with very little risk of their dying." At that time (1900) both seeds and cuttings were distributed by the United States Department of Agriculture. Some trees might have been introduced into Florida before that time, because the lebbek has been in the Bahamas a long while. I think it was there that it got the name of "Woman's Tongue," because of the rustling of its dry pods in the wind. Some students in the University of North Carolina who were working on this tree told me they found so much soluble starch in its wood that they nicknamed it the "potato tree."

When the trees are full of pods, as they are every year, the noise is bothersome. The enormous amount of seed shed by the lebbek insures its extension. It is a very

vigorous grower. A single tree is soon surrounded by a dense thicket of hundreds of little trees. It sheds a rich litter over the surface of the land. I have grown young lebbek trees in pots, and in the mat of fine roots close to the porous clay there are usually hundreds of white masses of nitrogen-fixing bacteria.

Considering the ease of propagation, the rapidity of growth, and the character of its

LARGEST SAPODILLA TREE FOUND BY THE AUTHOR IN SOUTH FLORIDA

THIS TREE IS LOCATED ON THE BLACK PLACE AT SNAPPER CREEK. IT BEARS THE LARGEST FRUITS OF ITS KIND THE AUTHOR HAS EVER SEEN: THEY ARE WHITE AND SOMETIMES 4 INCHES IN DIAMETER.

wood, it seems to be the ideal tree for which the paper manufacturer is hunting.

Many people have assumed that the wood is inferior in quality, but this is a mistake. According to Herbert Stone in his *Timbers of Commerce*, it is known in England as East Indian Walnut. It has various names in the Indian dialects, and India and adjacent parts of southeastern Asia appear to be its home. The wood weighs, when dry, from forty-one to fifty-six pounds to the cubic foot. In hardness it is comparable to English ash and although it has a rather coarse and open grain, the surface is lustrous and silky when finished. Stone says that in India it is used for sugar-cane crushers, oil mills, furniture, well curbs, wheelwork, and in South India for boats. The heartwood is a dark brown walnut color. There is usually a thick band of white sapwood; and young trees are usually all sapwood, which gives rise to the mistaken idea that the wood is soft and not of much value. The fact, however, that it is used in so many ways in India indicates that we are overlooking a good timber tree.

There are several trees, like the famous saman of Cuba or guango of Jamaica, and guanacaste in Central and South America, that are similar to lebbek All of these produce a hardwood with the general appearance of walnut for which they are sometimes substituted.

Brown, in his *Sylviculture in the Tropics*, says that the fine avenues of lebbek in Cairo were killed in 1910 by aphids. So far, in Florida, this tree seems safe from insect attack and disease. In India it has the reputation of being able to take care of itself. It is a tree that truly roots for a living. In the *Indian Forester*, G. M. Ryan says that root suckers of *Albizzia lebbek* have been found a distance of one hundred feet from the parent tree.

A constant cover of pine trees subject to frequent burnings, according to the best authorities, exhausts the soil. It is therefore imperative that, wherever possible, we use these leguminous trees for soil betterment.

The cultivation of several crops is impossible in the tropics without shelter trees, and

THE LEBBEK AS A SHADE TREE

THE LIGHT PATCHES AMONG THE LEAVES ARE POMPONS OF BLOOM, GREENISH-YELLOW IN COLOR.

CASUARINAS LINE A MIAMI SHORE

THESE TREES, GROWN FROM WIND-SOWN SEED ON AN OLD SPILLBANK, ARE ABOUT FIVE YEARS OLD.

the trees usually chosen belong to the bean family. These not only prevent erosion and afford shade to the ground, but also add to its fertility. The lebbek has been used to some extent for this purpose.

Lebbek is a tropical tree, but it can stand a lot of dry weather and was not injured by cold in South Florida in our last cold spell. Since it does so well in northern Egypt, it will probably grow in the central part of Florida. It flourishes on the rough, rocky land of South Florida. Its seed is most likely to germinate in crevices of the rock containing some humus. Whether we plant it or not, it is pushing ahead of its own accord, and in many places in the Redlands section the scaly-bark casuarina and the lebbek together are now very common. They may be the forerunners of the forest of the future in South Florida.

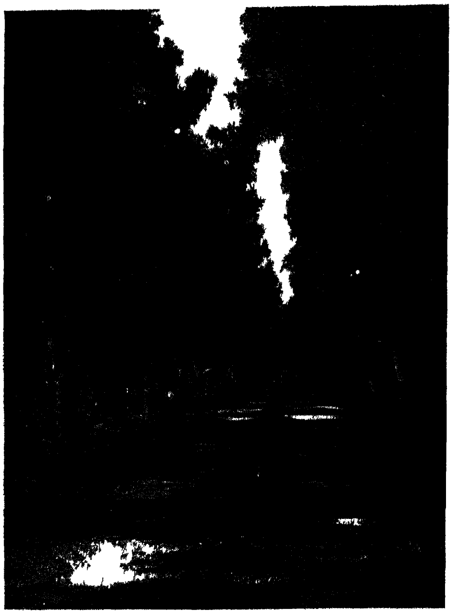
The lebbek bears flowers in pompon-like masses, greenish-yellow in color, and with a pleasant fragrance, whereas *Albizzia julibrissin,* common as an ornamental tree throughout the southeastern states, bears great masses of pink flowers in June.

The leaves of the lebbek are shed in the spring. At that time the great masses of papery pods are exposed and, although not decorative, are so unusual as to attract much attention. Were it not for the rustling noise and litter of pods, it would be far more popular as a shade tree. It is much used anyway because of its vigorous growth and comforting shade throughout the major portion of the year. According to O. F. Cook in his "Shade in Coffee Culture" (Bulletin No. 25, Division of Botany, U. S. Dept. of Agriculture) it is used for shade in coffee culture in the French West Indies where it is called *bois à friture* and *bois noir.* Its great value for fertility is shown in the analysis by M. Grandeau: 1000 kilograms of dry leaves contains nitrogen, 18.79 kilograms; phosphoric acid, 1.40; potash, 3.18; lime, 37.00; magnesia, 2.50. Cook also says that from the trunk a gum similar to gumarabic is obtained; also that the wood is hard, close-grained, veined with pink and red, darkening with age.

Casuarinas

Although natives of faraway Australia and the South Seas, these trees encircle the tropics of the globe. For binding shifting sand on the shores of the sea in windy situations, they have few, if any, equals. They may be trimmed into a windbreak hedge to such a height that homes in its lee will be protected in times of severe storms.

Casuarinas are called she-oak in some places and Australian pine in others but they are neither pine nor oak, although their wood resembles that of oak and in general appearance they are not unlike pines These



CAJEPUTS AT CHAPMAN FIELD
AMONG THE MOST POPULAR TREES FOR SHADE AND ORNAMENTATION IN SOUTHERN FLORIDA.

trees are also called whistling pine, Polynesian ironwood, beefwood and a host of other native names, but its scientific name, *Casuarina*, is not difficult and is appropriate since it means "with branchlets like the feathers of the cassowary bird." The branchlets are green, pendant, and without noticeable leaves. These trees are favorites of the natives of all sandy tropical shores and are highly praised by almost every forester in tropical regions.

There are many old casuarinas in South Florida. On the seashore of Biscayne Bay, not far from Homestead, there was a group of them called "The Cedars." For sailors these striking trees formed a landmark that was conspicuous for a long distance. They were the leftovers of an old nursery which had obtained the seed from Cuba.

Casuarinas grow on salt marsh, seashore sand, and rock and muck at the rate of ten feet or more a year under favorable conditions and they naturally grow straight into the air. They are long-lived and may reach a height of one hundred and fifty feet. Being gross feeders, they have a very extensive and sturdy root system. To uproot a stump two feet in diameter is a real job for both man and dynamite. They fruit abundantly while very young and are easily propagated from seed. They are easily injured by fire and cold, but are remarkably free from disease.

The common species is *equisetifolia*, meaning "with jointed leaves like horsetails." There is another species in the Redlands region. I am not sure who first introduced it and am not sure of its specific name, but think it is *C. lepidophloia*. It is a beautiful tree, especially adapted to a rocky limestone soil and characterized by the production of many shoots from its roots. It soon produces a thick barricade and can be easily and quickly propagated from these root suckers. This species is rapidly spreading throughout this region because many people like it better than the common original kind I believe that this species is dioecious and that we have only the male kind, for our trees produce no seed.

From a botanical standpoint the inflorescence of *Casuarina* is puzzling. The process of fertilization is primitive. The seeds form in a small cone and are released when the ripe fruit is dried in the sun. Its nearest relatives are the willows and walnuts.

The wood of casuarinas is pink, turning dark with age. It is heavy, hard, and strong and is excellent for fuel and scaffold poles. It produces an enormous amount of wood in a very short time on soils where few other trees will flourish. Like many other tropical woods, it is seasoned with difficulty. The trees should be sawn as soon as cut and then carefully piled in a ventilated, shaded place. Small straight poles of *Casuarina* could be quickly grown for various purposes; even, it is said, for paper. This wood is used for war clubs by the natives of the South Seas.

C. equisetifolia appears to do as well here as anywhere in the tropics. This tree seems very much at home on the Keys and for many years has been a favorite as a shade tree in Key West. Although not a native, this tree may be classed as a naturalized immigrant and is so listed by several botanists.

The Redland species (*lepidophloia*), with many little ones springing from the roots of the mother tree, naturally forms a group capable of withstanding the severest gales.

Wind hitting such an incline is diverted upward, forming a protected area of large extent in its lee. When growing in group form, the trunks are protected from the scorching and drying effects of the summer sun

These casuarinas may form a very welcome mantle of green if our native Caribbean pine becomes a thing of the past, owing to excessive cutting for lumber and fuel. Thus man, with the help of wind and fire over a period of many generations, slowly changes the face of nature

The Cajeput

The first mention of the cajeput as growing in America was, I think, in an article by me in the February, 1910, issue of *American Forestry*. The following is quoted from that article, "Camphor and Cajeput":

> The cajeput (*Melaleuca leucadendron*) is full of promise for the low, moist regions of the southernmost part of the state of Florida. Like the Australian pine, it withstands saltwater overflow. The growth of the cajeput on land subject to overflow along the shore of Biscayne Bay has been so rapid that its adaptability to such situations cannot be questioned.
>
> My trees are now twelve to eighteen feet in height and I received the seeds in a letter from Dr. Maiden of Sydney, Australia, about three years ago. [That was in 1906.] They are already blooming profusely and yielding an abundance of seed. The flowers are at times covered with honey bees. It is, therefore, probably a great honey-yielder.

CAJEPUT IN THE EVERGLADES
THE CAJEPUT IS A NATURAL SWAMP TREE THAT GROWS IN BOTH FRESH AND BRACKISH WATER.

SEEDPODS OF THE CAJEPUT
WOODY CAPSULES ARE FILLED WITH SEEDS AS FINE AS DUST AND EASILY GERMINATED.

This same tree was introduced a few years later on the West Coast of Florida by A. H. Andrews of Estero. Since that time it has spread naturally in the Everglade region and should now be classed as a naturalized species. It is one of the most popular trees for shade and ornamentation at Miami Beach and other similar places. The leaves yield a valuable oil. The wood is heavy, hard, durable, and light brown in color. The profuse masses of white flowers yield an abundance of nectar. The bark is thick, punky, and excellent for insulating purposes. What recommends it to many is the beauty of its straight, white stem, and masses of delicate foliage. It grows with great rapidity and while very young produces very small seeds in hard, woody capsules the size of small peas. It is not destroyed by fire because of the thickness of its corky bark. It is a natural swamp tree in both fresh and brackish water. It withstands strong winds. From a silvicultural point of view it has few, if any, equals in the plant world.

Its seeds can be scattered from a saltcellar

over the surface of the water. Nature does the rest. We had trouble trying to germinate these little seeds in soil in the usual way. Little did we suspect that all we needed to do was to scatter them over the water and mud of the swamps and that in time they would actually spread into the wild cypress swamps and hold their own against native trees. The cajeput is being introduced into the Bahamas where it will find a congenial home around brackish lakes or in deposits of muck.

The scientific name of the cajeput is *Melaleuca leucodendron*. *Melas* means black, *leukos* white, and *dendron* tree. It is called black-white tree because in its native land, owing to bush fires, the lower part of the trunk is black. The word cajeput, sometimes written cajaput or cajuput, comes from a Malay word meaning "white tree," for it has a bark that is usually very white and papery, like the northern birch. Its long withes, somewhat similar to the olive, are excellent for garlands. The leaves have a fragrant odor arising from the oil which they contain.

Cajeput oil is distilled from the leaves. It is a slight irritant externally, but less so than turpentine. It gives a sense of warmth internally and causes an accelerated pulse. It is said to have medicinal properties. The main supply of cajeput oil came from New Caledonia via Marseille, France. Like many other products of tropical plants, it could be produced in South Florida and nearby islands.

A few seeds in a letter from far-off Australia, a few trees started, and finally there is a changed landscape. No one can predict what he will do when he drops a seed from foreign parts in a new environment. If it happens to be a weed, he may regret it, but if it is an ornamental and useful tree, he has done well for himself and posterity, especially if, as in this case, it meets with popular approval.

(To be concluded)

GARDEN ISLANDS OF THE GREAT EAST

From now until the boat returned to Java, our trip resembled an enchanted cruise. During the next twenty days we made eighteen stops at islands varying from a few square miles in size to the immense terrain of New Guinea. At each place we met different types of natives who had grown up on their respective islands knowing nothing of the world beyond the waves breaking on their white beaches. These people spoke different dialects, or different languages, came of different racial stocks, and had their own individual civilization. These islands of the Malay Archipelago form a group so unique that I have always longed to return there. I would have been extremely unhappy when we sailed away had I realized I should never see them again. [But Dr. Fairchild did see them again after all (see the review of *Garden Islands of the Great East* on page 77 of this issue)].

* * *

I was unable to go ashore at several of the islands, for I came down with an attack of malaria. Our servant, Pandok, insisted on rubbing me with cajeput oil—the first time I had ever heard the word. I little dreamed that the oil came from the leaves of a tree (*Melaleuca leucadendron*) which I would later help John Gifford to disseminate throughout South Florida and which would naturalize itself there until today thousands of cajeputs are growing wild in addition to the thousands planted in gardens as ornamentals.—From *The World Was My Garden* by David Fairchild. Quoted by permission of the publishers, Charles Scribner's Sons.

SCHOOL OF PAN AMERICAN AGRICULTURE

By CHARLES MORROW WILSON

ARNULFO MERCADO, a farm boy from remote San Marcos, Honduras, was leaving home for the first time, with good and sufficient reason. He was going away to school.

The time was right, since the Mercado corn and beans were harvested, the millet was threshed, and the peppers were drying on the red tile roofs. Arnulfo, who is 19, weighs 200 pounds, and stands almost six feet, was eager for the journey which would lead him towards what is called higher education.

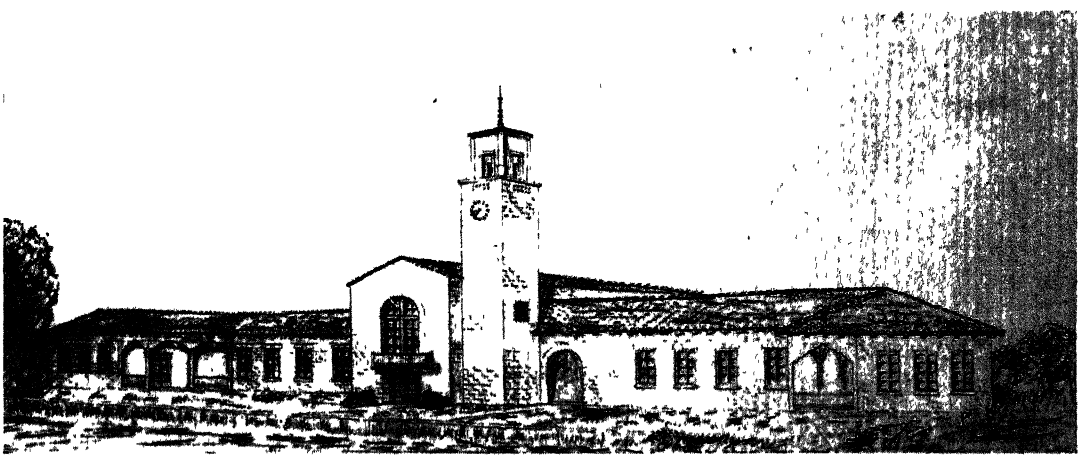
The latter is not ordinarily available in rural Honduras, or indeed in tens of thousands of rural communities throughout Latin America. Usually, beyond the capitals and other principal cities of the other Americas "college" and "university" are little more than attractive words. As an over-all average in terms of U. S. public school establishments, the common schools of nonurban Latin America provide the approximate equivalent of the first four elementary grades.

About seven years ago Arnulfo was graduated from his local grade school where he studied hard, learned easily, and viewed any additional schooling as a pleasantly whimsical pipedream. Resolved to do his best with the means at hand, Arnulfo went to work on his father's little farm. One day recently the mayor rode out to the Mercado home bringing word that Arnulfo had been chosen to study agriculture in a new school which is being built in the high, lush valley of Honduras' Yeguare River.

Enormously happy, Arnulfo put on his Sunday suit, traded embraces with his mother and father and younger brothers, and walked to the village to share thanks with the local padre. Then he asked Alfredo, his next younger brother, to ride with him, and lead home the horses.

Accordingly, the Mercado brothers rode through a hundred miles of jungles and over the many thorn-bush hills that separated Arnulfo from the interesting abstraction called the higher education in agriculture. It required three hard days of riding to reach the Hacienda Zamorano at the crossing of the respective roads to Danlí and Guinope, some thirty miles below Tegucigalpa, Honduras' unique mountain capital.

Many new buildings are rising on the site of the once-famous hacienda; all built in colonial Honduran architecture—with granite and stuccoed walls, red tile roofs, and handsome hand-carved wooden doors. The Mercado brothers looked down at this place for the higher education and watched other youths strolling curiously about the grounds;



ADMINISTRATION BUILDING OF THE ESCUELA AGRICOLA PANAMERICANA

youths who had come by muleback, or slow train, or roaring plane from Mexico and all the six republics of Central America.

Then the Mercado brothers parted, shaking hands in the manner of mature men Alfredo, 17, set out for San Marcos, riding his own horse and leading Arnulfo's.

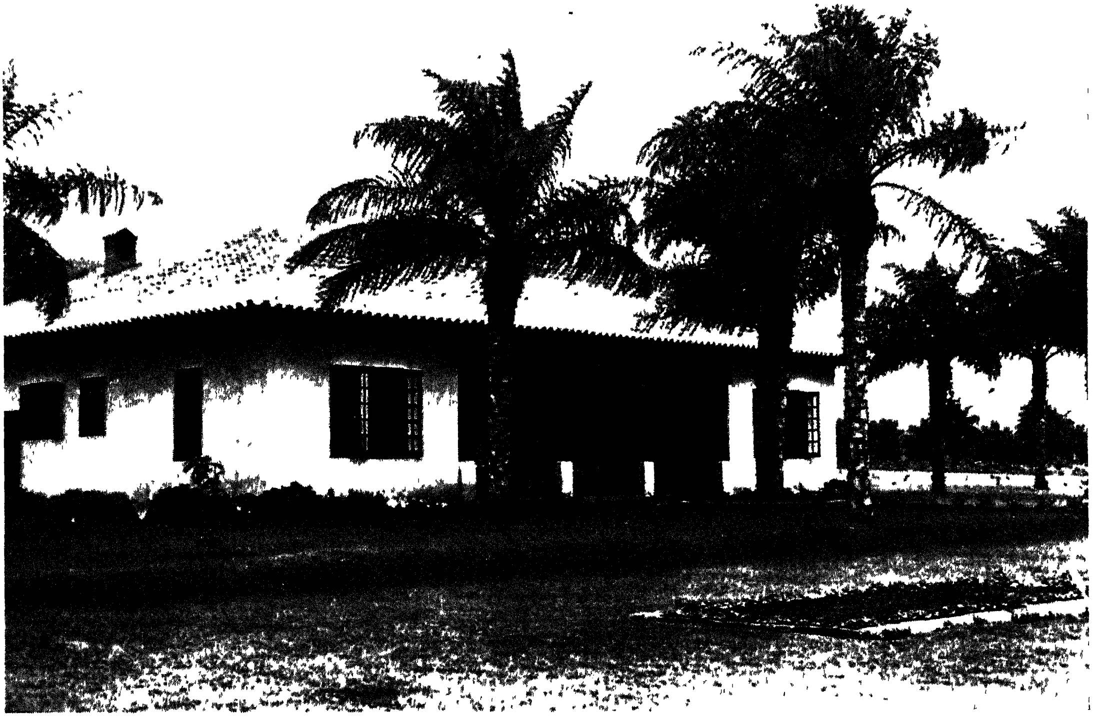
Being afoot, Arnulfo walked to the new campus. An instructor, newly arrived from Costa Rica, greeted the new arrival and saw him equipped with the school's uniform, which consists of denim breeches and work shirt, sturdy brogan shoes, plain underwear and socks, a farmer-style straw hat, and (for Sunday wear only) an attractive white linen suit. Then the instructor explained: "At this Escuela Agricola Panamericana you will be one of a family of young men from many nations of the Americas. All come to the school to work and learn and to carry home to their own farms or communities the good of what they have learned. You do not need money here. This school provides all your needs, including doctor, dentist, and barber. The boys with whom you will work and play are of your own kind; farm raised, good character, intelligent young men who will make good use of their work and study at this school. They are over sixteen and under twenty-one; for the most part the sons of farmers and tradesmen. Their blood is principally Indian. Of our first seventy-three scholars at least sixty are part Indian. None is rich; none is unfriendly to work."

Arnulfo found the courage to confide: "I am not a scholar, Señor. I've had only a few terms of schooling."

The instructor showed no particular concern. "Here no student is required to have more schooling than his home countryside affords." Arnulfo continued, "I have never had the chance to learn English, Señor." The instructor said: "You will learn to speak and write English well; also, you will learn to speak and write Spanish better. You will learn these two American languages in the company of many other Americans."

The instructors called together a group of the newly arrived scholars- Mexican, Salvadorean, Guatemalan, Costa Rican, Nicaraguan, Panamanian, and Honduran, and be-

BEGINNING OF BUILDINGS FOR THE ESCUELA AGRICOLA PANAMERICANA



A TYPICAL FACULTY RESIDENCE

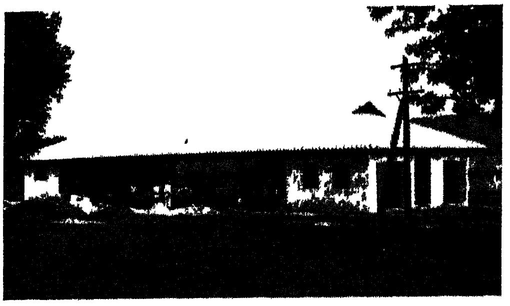
gan to show them over the far-spreading campus. The grounds cover 3,500 acres—about 5½ square miles—and include forested mountainsides a mile high, along with hundreds of acres in fertile valley fields. The average altitude is about 2,600 feet; high enough to grow many northern cereals, vegetables, and deciduous fruits, but warm enough for most important crops of the true tropics. Arnulfo noticed that several hundred native workmen are busy building the far-spreading college; that men and oxen take ponderous cartloads of volcanic rock from a nearby quarry; that other work crews are felling native white pine and sawing it to timber; that still others are molding and kilning red brick and tiles from local clays. Four faculty residences and a staff dormitory are already completed, and of the four stone dormitories for students, the first is completed and occupied. The "gran" building, also of stone and tile, early Honduran style, is big and imposing and climaxed by a splendid sixty-foot tower. The expansive campus is also marked for games—baseball, track, football and basketball, and a boxing ring. This school of Pan American agriculture will be opened formally on Columbus Day, 1944. But in response to the urgent need for such a school and an avalanche of applications for fellowships, the first entering class was accepted in 1943.

The instructor also pointed out the newly built animal sheds and barns and the cold storage house, and beyond them the lines of gardens and experiment fields. "Some of the crops have grown well even this first year. But some have turned out poorly. . . ."

An Indian youth from Nicaragua suggested, "Maybe not all the planting was made at the right time of the moon. . . ."

The instructor smiled and nodded: "Yes, and perhaps there are other reasons which you and I must study and find out." He pointed. "There to the right you see some fine melons. Down the bend there are several hills of cucumbers. Something went wrong with them. The leaves have curled and the stems have rotted away. . . ." The instructor added, "We are here to study and learn for ourselves, Señores, not merely to quote what others have said."

Next day, September 1, 1943, was the first day of school. At five A.M., while the mesas



BUILDING A MILK SHED

were still inky black, a gong sounded and the students began to emerge from the dormitory. Arnulfo had been impressed by the fact that the dormitories are successions of rooms instead of open barracks. Promptly at six the gong (made from an ancient church bell) sounded breakfast, a plentiful fare of fried beans, white cheese, scrambled eggs, bread, fresh butter, and all the coffee and milk that the hungry youths wanted. After breakfast the students were assembled and divided into groups—about twenty-five to the group, for "practica," wherein each crew is given a month's assignment, one to work in the gardens, another in the dairy barns and horse corrals, another at field tillage, and so on.

After a month of each type of work, each crew is moved to another assignment; each student spending four hours of each week day at practical and well-supervised farm work. When the first morning's work was finished (it was punctuated by much explanation and discussion), all crews returned at eleven for lunch, which is served in a handsome stone mess hall. Again the scholars were hungry, and again the food proved satisfying; thick soup, boiled beef, white potatoes, green vegetables from the school's extensive gardens, crisp tortillas instead of bread, and plenty of oranges.

After lunch come three hours in classes. The beginning course includes an hour's class in English, an hour of mathematics, and an hour of elementary science—chemistry, physics, geology, and botany, with accent on valid training in basic scientific principles.

When the classes were finished at four, the students joined in their first recreation period—two hours of whatever sport they select. Arnulfo chose baseball and played with all his might until the supper gong sounded at six. Again he was hungry, and again he ate plentifully of beef, beans, tortillas, cabbage, and milk. After supper comes the "visiting period" in the recreation hall and due opportunity to listen to the radio or write letters or play cards or checkers, and once weekly to see a motion picture. Then comes the study hour, in the student quarters. Lights go out promptly at nine.

That was a typical day at Escuela Agricola Panamericana, a free work and learn school for boys of the American tropics; a school course which lasts three years, with a fourth or specialization year for students who show outstanding promise. The school is apace with the Central American tradition for a poor man's self-made leadership. Its graduates are urged to and are prepared to return to their own countrysides or farms, or to qualify themselves for helping their respective governments along lines of agricultural extension work or otherwise improving the indigenous agricultures of the American tropics.

The School of Pan American Agriculture has been established by the United Fruit Company with initial grants totalling $800,000. Early in 1942 the National Congress of Honduras authorized the location of the school within its boundaries, and lands and building sites for the unique college were purchased with the initial donation. When completed, the physical plant will cost upwards of $1,000,000. Paying the entire sum, the United Fruit Company pledges the permanent maintenance of the school, which will endure exactly so long as the company endures.

Physical properties of the school include

BULL PEN FOR OUTSIDE FEEDING

VIEW OF THE SCHOOL'S FIRST VEGETABLE GARDENS

a horticultural section, with nurseries, orchards, and vegetable gardens; and a livestock section, equipped with dairy barns, stables, pig sties, chicken houses, and refrigeration and creamery buildings. The school's forest lands extend westward into the mountains. Down the valley are the experimental fields and pastures, the former being planted with corn, beans, rice, potatoes, and other annual crops. The range is being developed as model livestock pastures. The school supplies its students with all necessary books, laboratory equipment, tools, and other supplies—without cost to the student. In fact no student pays a penny or centavo for his schooling. And no student is exempted from work.

The curriculum is carefully geared to the practical agrarian leadership of the American tropics. Besides the first year of English, general science, and mathematics, the three-year schooling includes courses in farm bookkeeping, land survey, soil analysis, and basic farm engineering. In addition, all students receive elementary instruction in anatomy, physiology, hygiene, and first aid, with particular emphasis on the treatment of common tropical diseases such as malaria and dysentery. The study of farm economy includes courses in marketing tropical products, also farm credit and rural legislation (legal matters pertaining to enclosures, land limits, roadways, quarantine practice, livestock laws, and trade regulations).

The department of agronomy provides basic laboratory experiments in chemistry and geology, which is followed by training in classification of soils and the use of fertilizer and crop rotation techniques as adapted to common needs of the American tropics. The forestry course includes the replanting of native trees, the establishment of tree nurseries, and the transplanting of small trees from nurseries to open woodlands. The course in agriculture begins with practical instruction in the propagation of common plants by means of seed, sprouts, bud grafting, and rhizomes. Each student prepares and cares for several hundred grafted fruit trees including oranges, mangoes, and avocados, with all trees becoming the student's property at the time of his graduation. The courses in practical gardening include the planting and management of home gardens and the production of green vegetables to sell; also the study of the nutritional value of the common vegetables.

The farm engineering department directs the study of irrigation and drainage; doubly important in Caribbean lands where drainage is practically essential to all crops of the wet tropics and in most highland areas where well planned irrigation helps assure larger, more uniform, and more profitable harvests. The courses in farm engineering also teach the use and care of farm machinery, including tractors and tractive implements as well as the standard hand tools and horse-drawn implements. Instruction in home carpentry and farm blacksmithy is included; also in building and maintaining roads. The

department of animal industries provides practical tutelage in breeding and keeping cattle, horses, mules, swine, and poultry in the American tropics, where livestock resources remain chronically insufficient. Practical work in animal health includes the study of principal contagious and infectious diseases and parasites of livestock in the tropics.

In the United States the opening of another professional school is not necessarily newsworthy. But south of the Rio Grande agricultural, mechanical, and engineering schools are still in dire shortage, and poor country youths have slight chance of attending the national universities. In general, too, Latin American college and university training remains centered in law, medicine, and the classics. Though more than four-fifths of the lands of the other Americas are tropical and though at least 70 per cent of all Latin Americans live from farming, scientific education in tropical agriculture remains lamentably scarce. Meanwhile, the technical and commercial problems in tropical agriculture are growing almost fabulously. Defense of basic crops and livestock against fungi, pathogenic microorganisms, and insect enemies becomes an unending and ever more difficult obligation. Problems of soil conservation grow at a terrific rate.

Furthermore, the new crops now finding their way into the economies and agricultures of the American tropics including such promising export commodities as abaca, cinchona, essential oils, strategic timbers, rotenone, rubber bearing plants, and urgently needed tropical fruit crops require more and better research and experimentation. The proposition grows ever more evident that if Latin American citizen farmers are to grow, develop, and benefit from the great crops now being proved in the New World, the indigenous farm youth must be helped to learn the demanding techniques of modern tropical agriculture. Escuela Agricola Panamericana is a first deliberate answer to this challenge and need.

Arnulfo Mercado and the seventy-two other Central American and Mexican youths know how urgently and desperately their countries need technical education in agriculture. At first hand they have witnessed

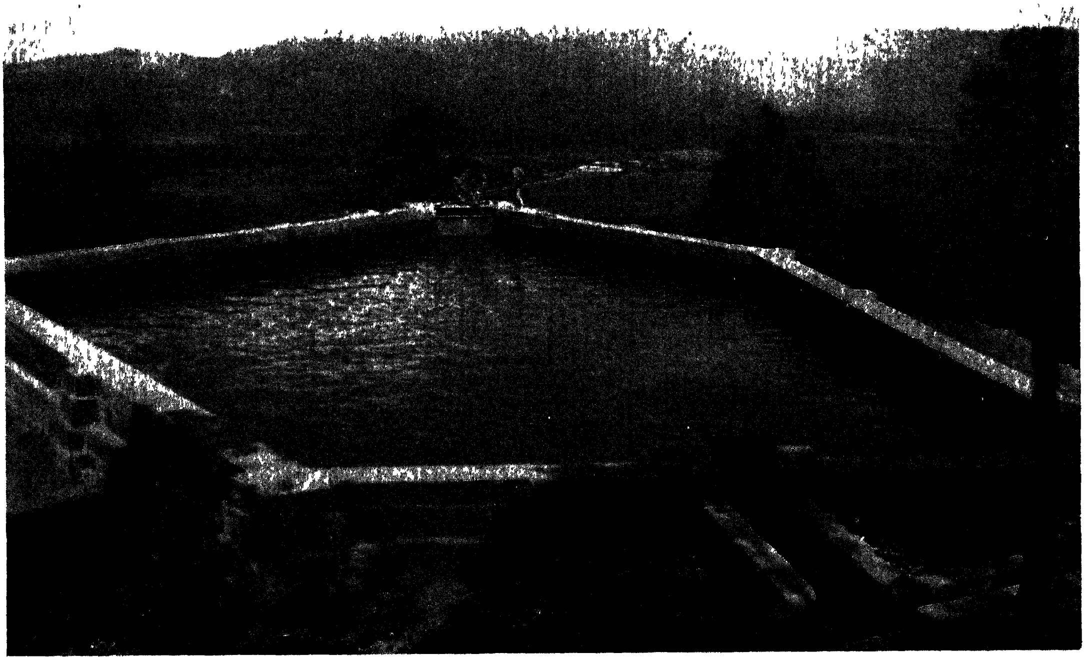
SCHOOL PASTURES AND RANGES DEVELOPED FOR STUDENT USE

the needs. And not one of them is too young to know that agriculture succeeds because of the sweat, toil, intelligence, and skill of the citizen farmer, particularly the small farmer. Accordingly, Arnulfo and his associates are hard at work and hard at play at a school which they know is in and of Honduras and Central America.

The food, the language, the gaiety of the backwoods, indeed, the architecture are those of the American tropics.

The four dormitories (the first is completed and occupied) are named to honor great heroes of Central America—Morazan of Honduras, Barrios of Guatemala, Mora of Costa Rica, Delgado of El Salvador. All buildings are made of local products, by home talents and native labor; a force of about five hundred Central American workers who quarry, kiln, saw, and build with materials immediately at hand. Power and light are supplied from the school's hydroelectric plant already completed on the higher reaches of the Yeguare River. The infirmary, now in building, will include an emergency hospital, a clinic room, a dental clinic, and a barber shop. The school has a staff barber who administers one free haircut to every student once a month; and more significantly, a physician-surgeon. Prior to their arrival at the school, few of the students had any dental attention and almost all require dentistry, which is being provided.

Student health is excellent and appetites are lusty. Arnulfo and his fellow students are learning how to plant, till, and harvest the good foods which nourish them. Even during the beginning year the school is producing most of its foodstuffs. Fields and gardens are already planted and in bearing. Livestock holdings are ample to meet the needs of both students and workmen. Already garden crops and other staple food crops have been adapted from various nearby Americas; melons from Cuba, sweet corn from Puerto Rico, grafted avocados from California and Mexico; white potatoes from Florida; tomatoes and leafy vegetables from various areas of southern United States.



WATER STORAGE FOR OPERATING THE 40-KILOWATT POWER PLANT

Accordingly, Arnulfo and his freshman classmates have opportunity to benefit by good eating, which in Honduras or anywhere else is the maximum dividend of good agri-

culture. That is a cosmopolitan goal and these young men of the American tropics are aided by a cosmopolitan faculty. For example, the head of the department of agronomy and soil is Alfred F. Butler, co-builder of the Lancetilla Experiment Station of Honduras, an English trained agronomist. H. A. Von Wald, of the University of Wisconsin, is head of the department of engineering. The head of the livestock department is E. A. Rivera, a native Puerto Rican, a graduate of the College of Agriculture of Mayagüez, Puerto Rico, and recently director of the livestock and dairying department of the Venezuelan Government. The professor of natural sciences is a Costa Rican, until recently the director of the National Museum of Costa Rica. The professor of English is Augusto Arias, a Guatemalan. The professor of horticulture and director of the school is Dr. Wilson Popenoe, internationally known authority on tropical agriculture; a former associate of the U. S. Department of Agriculture.

The seven regents of the school, five of whom are Central Americans, select the scholars, who must be proved thoroughly accredited as to good character, industry, and general intelligence. Thus far all admissions have been of poor boys. The school would thwart its purpose by accepting or requiring money from students. It cannot directly imitate the curricula or establishments of any college in the United States, however meritorious, since an excellent United States college is rarely, if ever, the right school south of the Rio Grande. Therefore it must create a new formula for practical Pan American education, a task which it is now undertaking.

SHALL WE SPEAK OUT?

From multiplex experiential fronts
We must at times to inner room withdraw
And ponder meaning in some hope to see
Synthetic bits of universal law.

Too oft emerging from that cell to light
We bring no message, yet discern the flaw.
Upon that page our shadows fell so dark
That what we drew but outlined what we saw.

At times the ego merges with the All
And lets the light of truth prevail.
Then do we feel impelled to sing
Or picture nature's wondrous tale.

Is this so strange for those immersed
In scientific lore, whose life is spent
In analytic test and measurement,
Of changing form and planned experiment?

Truth comes in many forms, and beauty too,
May peer from graphs and metric formulae.
The reach of mind beyond its data soars
To make its greatest gains, and we are free
To test and seek some more.

Mankind is still emotion geared
With hymns of hate and love.
Behind the scenes stalk want and fear
And over all the crowding sphere
The master problem proves.

So therefore build and carve and draw,
Deduce, conclude and write as law
What seems so clear to you.
Fear not to seem beyond the pale
For yet no sacred mode prevails
To voice a message true.

—JOHN G. SINCLAIR.

UTILIZATION OF SEAWEEDS*

By C. K. TSENG

INQUISITIVE children often ask their elders about the heaps of rotten plants washed ashore on the beach. A typical answer is, "Oh, they are seaweeds." To most persons who enjoy swimming or strolling along the beaches seaweeds are very unwelcome. Probably when the early Latin scholars, such as Virgil and Horace, spoke of these plants as "*villior alga,*" they had the same feeling too, for could there be anything more worthless and noxious than the seaweeds which spoiled the otherwise clean and lovely beaches? In fact when a Roman had said that something was more worthless than an "*alga,*" he had probably gone as far as the Latin language could carry him!

The thrifty Orientals, however, have quite a different attitude toward marine growths. Although they too regard most of the marine plants as weeds, they call certain kinds "sea vegetables." The latter are so highly esteemed as food that natural production is not sufficient to satisfy the demand for them and consequently they are cultivated like farm crops. Moreover, some marine algae have long served as medicine and others have been employed in sizing silk and for various other purposes. To those who know the value of marine crops, it seems inconceivable that the useful forms should have been called sea "weeds."

In the last two centuries utilization of seaweeds has been gaining favor in the Western world. While the food-conscious Orientals have been using luscious marine plants chiefly for subsistence, the industrially-minded Occidentals have developed other uses. Previously they were burned to form kelp ash from which soda, potash, and iodine were extracted. Now they are processed to yield algin, agar, carrageenin, and other useful products. Few realize, however, that the United States is annually deriving millions of dollars worth of valuable products from these humble plants.

Some eighty years ago, E. C. C. Stanford, the discoverer of algin and one of the pioneers in the promotion of seaweed industries, addressed the Royal Society of Arts in London on the economic applications of algae. The following statement made by the chairman after the lecture could represent the opinion of those who have come to realize the value of marine plants:

> It had been remarked by those who noticed the progress of invention that language generally had to undergo changes corresponding with the changes of the times. Now he, for one, wished that the word "weed" should cease to be applied in the indiscriminate manner it was to marine plants. Hitherto "weed" meant a useless or noxious plant. Mr. Stanford had shown that a vast proportion of marine plants, so far from being "weeds" in the ordinary conception of the word, were extremely useful "vegetables"; and he hoped they would come before long to limit the word "weed" to those marine plants which were worthless, or which were not capable of being turned to accounts.

Unfortunately, there is as yet no simple word to take the place of "seaweed" in its general sense so that we might differentiate between the useful and the useless plants of the sea. Illogically we still have to use the term "seaweed" in the same indiscriminate way that was criticized almost a century ago, unless we want to use the more technical combination, "marine algae."

To people who have never enjoyed the taste of some delicious sea vegetables it may seem inconceivable that seaweeds or their products could be eaten. Nevertheless, they are unconsciously consuming certain seaweed products, which have, in recent years, entered into our daily diet. To mention some examples: many types of confectionaries, canned goods, the so-called health foods, and practically all ice cream and chocolate milk contain seaweed extracts.

USES OF SEAWEEDS

The chief uses of seaweeds may be classified under the following five categories: foods, drugs, gums, chemicals, and stockfeed and fertilizer.

Foods. More than one hundred kinds of

* Contributions from the Scripps Institution of Ocenography, New Series, No. 229.

About one-fifth actual size

FIG. 1. *LAMINARIA JAPONICA**

YOUNG JAPANESE KELP PLANT FROM CHEFOO, CHINA. A COMMON FOOD SEAWEED ON THE ORIENTAL MARKETS.

marine plants are utilized as food by the Chinese, Japanese, and Hawaiians. Of these kelp and purple laver are consumed in larger quantities than all the others combined.

The edible kelps in the Orient are species of *Laminaria*, *Undaria*, and *Ecklonia*. The most important is *Laminaria japonica* (Fig. 1), which is known in China as *haitai* and in Japan as *kombu*. The Japanese probably eat their kelp as regularly as the Americans eat their lettuce and tomatoes. The Chinese do not consume as much kelp as the Japanese, because China produces only small quantities of it. Annually, she has imported about 55 million pounds of *haitai* from Japan, and in spite of its foreign origin, it has been sold in the inland provinces thousands of miles from the ports of entry.

The purple lavers are members of the genus *Porphyra*, called by the Chinese *tsuts'ai* and the Japanese *amanori*. The demand for this group of sea vegetables, especially *Porphyra tenera* (Fig. 2), is so great that natural production both in Japan and in China is not enough to meet the demand. Consequently, it is extensively cultivated in Japan, where a total area of over twelve thousand acres is devoted to *amanori* farming. Annually over 65 million pounds of this seaweed, valued at about 9 million yen (about $3,000,000), were produced, some of which was exported to China.

Scientists do not entirely agree on the food value of seaweeds. Experiments have shown that some seaweed carbohydrates are not easily digested by humans because of the absence of suitable enzymes in the alimentary tract. Research on others indicates a rather high degree of digestibility. We still do not know enough about the actual nutritional value of seaweeds. Possibly, like the land plants, some have a high nutritive value whereas others have very little or even none.

Seaweeds are comparable to lettuce and celery. Whether they have high nutritive value in the sense of supplying energy and building tissue is of secondary importance. Because they are stimulating or appetizing,

About one-fourth actual size

FIG. 2. *PORPHYRA TENERA*

THE PURPLE LAVER OF THE ORIENT, ANOTHER COMMON EDIBLE SEAWEED ON THE MARKETS OF THE FAR EAST

* Figures 1, 2, 3, 6, 7, and 8 are reproduced through the courtesy of Professor Wm. Randolph Taylor, University of Michigan.

because they supply necessary salts in readily available organic form, and because they furnish vitamins, seaweeds should have a place among common foods.

It is possible that a seaweed diet may be a preventive for hay fever. Although plants having more virulent pollens than those from the American ragweeds are found to occur in Japan and coastal regions of China, yet these areas have few hay fever cases. But Orientals are not immune to such allergy; in fact, many of them become hay fever victims after having stayed in the United States for some time. It is generally accepted that potassium chloride may help to alleviate suffering from hay fever. Since the Japanese and the Chinese eat many kinds of seaweeds that contain large amounts of potassium chloride, it is probable that the custom of eating seaweeds may be responsible for the suppression of hay fever in the Orient.

Drugs. The Chinese *Materia Medica* has recommended, from early days, the use of seaweeds, especially the kelps and the sargassums, in the treatment of goiter and other glandular troubles. These plants have also been used in the treatment of dropsy. The ancient peoples, of course, did not know why such seaweeds were so effective in curing these maladies. They found out the special value of the humble marine plants merely by trial and error. Now, the curative principle is known to be iodine.

About one-half actual size

FIG. 3. *DIGENEA SIMPLEX*

FROM CHINA. AN IMPORTANT ORIENTAL DRUG PLANT FROM WHICH MACNIN AND HELMINOL ARE EXTRACTED.

About one-half actual size

FIG. 4. *GELIDIUM AMANSII*

A YOUNG CYSTOCARPIC SPECIMEN OF THE PRINCIPAL AGARPHYTE IN THE ORIENT. FROM TSINGTAO, CHINA.

A well-known drug on the Oriental market is the tropical seaweed, *Digenea simplex* (Fig 3), known in China as *Tserkoo-ts'ai* or *Haijen-ts'ao.* In recent years the Japanese have prepared a drug from it called *macnin.* A pharmaceutical under the name of *helminol* also comes from the same source. It is said to be as effective as the standard vermifuge, santonin, and, because it has no secondary bad effect, especially on children, it is rated as better.

Gums. Seaweed gums are hydrophilic colloids which form mucilaginous sols or firm gels in water at low concentration. Agar, algin, carrageenin, and funorin are the four kinds of gums made from seaweed sources. Because of their peculiar properties, they have been used extensively as stabilizers, deflocculants, textile sizers, and semielastic media. Their commercial importance has increased rapidly in recent years.

Agar is extracted principally from species of *Gelidium* (Fig. 4). Although agar in the

About one-fifth actual size

FIG. 5. *MACROCYSTIS PYRIFERA*

YOUNG GIANT KELP PLANT, FROM WHICH ALGIN IS MADE IN CALIFORNIA. SPECIMEN FROM LA JOLLA.

form of a jelly has been eaten by the Orientals for ages, it was not until the middle part of the seventeenth century that the process of preparing its dried form by a simple freezing and thawing method was accidentally discovered in Japan. As a stabilizer and a gel-forming substance agar has numerous applications. In some of its special uses there is as yet no successful substitute. Since the outbreak of the war it has attracted considerable attention in this country. More than 90 per cent of the agar consumed in the United States formerly came from Japan. Since the war the California agar industry has greatly increased its production and is now making enough agar for essential uses in this country.

The most important service that agar renders to mankind, in war or in peace, is as a bacteriological culture medium. In dentistry it serves as an impression mold. Its extraordinary water-holding ability makes it valuable in wound dressing and as a laxative. In the photographic industry it replaces gelatine for certain types of films. In the hot drawing of tungsten wire agar is used in making a special lubricant to facilitate the operation and to reduce the wear on the die. It is also extensively used in bakery products, in clarifying liquids, in making health foods, in confections, and in ice cream. Recently it has been used in the manufacture of marine storage batteries.

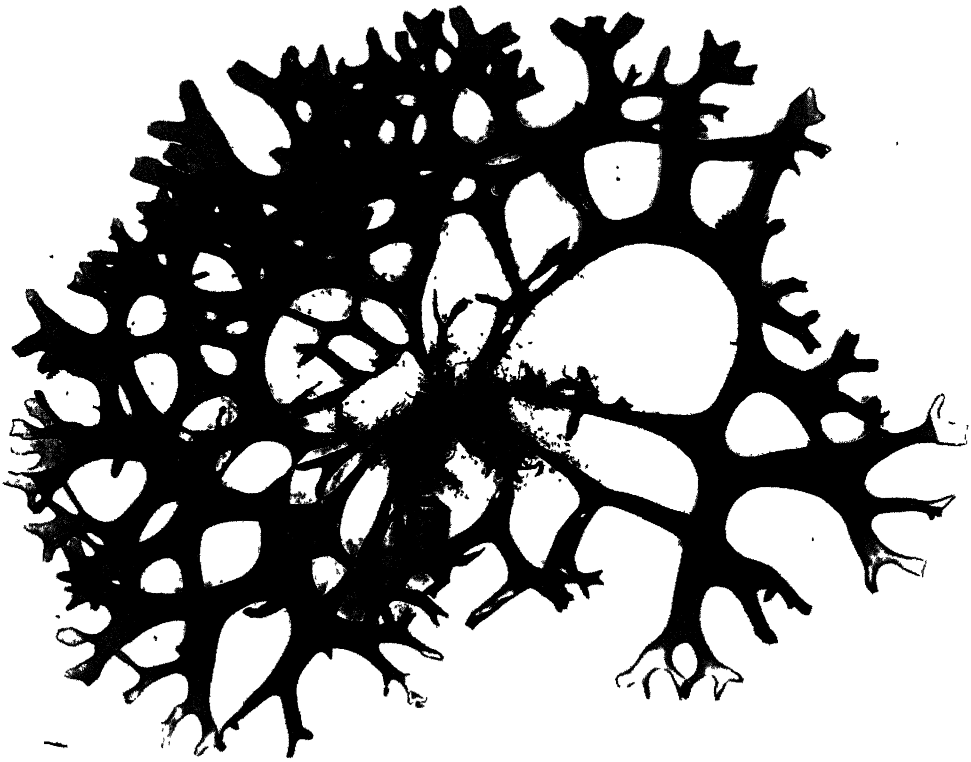
Algin is derived from the giant kelp, *Macrocystis pyrifera* (Fig. 5), on the West Coast, and from various species of *Laminaria* (Fig. 6) on the East Coast as well as in England, France, and Japan. The term generally refers to the water-soluble salts of alginic acid, especially sodium alginate. It was discovered in 1883 by the English chemist, E. C. C. Stanford.

The important use of algin is as a stabilizer in the manufacture of ice cream. It is also a valuable agent for thickening, emulsifying, suspending, and coating various sub-

About one-fifth actual size

FIG. 6. *LAMINARIA SACCHARINA*

FROM WEST BARNSTABLE DUNES, MASS. A VALUABLE EAST COAST KELP FOR THE EXTRACTION OF ALGIN.



About actual size

FIG. 7. *CHONDRUS CRISPUS*

THE WELL-KNOWN IRISH MOSS OF THE ATLANTIC COASTS, A SOURCE OF THE GUMLIKE SUBSTANCE, CARRAGEENIN.

stances. It is used in camouflage paints, fire-proofing compositions, latex coating for signal wires, and water-treating compounds. It is also utilized in making pharmaceuticals. Recently discovered is its use as a coating for oilproof paper containers.

Carrageenin is the cold-water-soluble extract from Irish moss, botanically *Chondrus crispus* (Fig 7). The seaweed itself was used extensively and exclusively, in earlier times, to prepare the well-known dessert, blancmange. About a hundred years ago the United States used to import large quantities of this seaweed from Europe at a cost of as much as two dollars a pound. It was later discovered that the same plant grew in great abundance in the cooler waters of the Atlantic Coast. For the past century, Scituate, Massachusetts, has been the center of the American Irish moss industry. Lately, large quantities have also been harvested in Maine. A recent estimate placed the production of *Chondrus* on the Atlantic Coast at about five million pounds per annum. It is generally agreed that Irish moss extract is one of the best agents for stabilizing the chocolate fibers in making chocolate milk.

Funorin is the gluey substance in the seaweed *Gloiopeltis* (Fig. 8), known as *funori* in Japanese and *hailo* in Chinese. Commercially, the entire, dried, frequently bleached seaweed is used without extracting this gluey principle from the plant. It is readily soluble in lukewarm water and may be identical with, or at least closely related to, the Irish moss extract. It is mainly used in sizing textiles, especially silk, and in this respect is said to be better than carrageenin. Japan produces about four and a half million pounds annually. China, although the second largest producer, also imports some from Japan to supplement her insufficient supply.

About one-third actual size

FIG. 8. *GLOIOPELTIS FURCATA*
FROM CHEKIANG, CHINA. IN THE ORIENT A GLUE OBTAINED FROM IT IS USED FOR SIZING TEXTILES.

Chemicals. During the eighteenth century one of the chief sources of potash and soda in Europe was seaweed ash. At the beginning of the nineteenth century, Scotland alone produced annually about twenty thousand tons of kelp ash, worth about forty thousand pounds sterling. When the manufacture of soda from common salt commenced early in the nineteenth century, the value of seaweed ash dropped rapidly. With the discovery of iodine in 1812, the value of kelp gradually increased until 1873 when iodine began to be recovered from the mother liquors obtained in the manufacture of sodium nitrate from *caliche*. The kelp industry then declined for the second time. The first World War stimulated the revival of the kelp industry in the United States and in other countries as a source of badly needed potash, which used to be a German monopoly, as well as iodine, acetone, and calcium acetate. Soon after the cessation of hostilities, the kelp factories folded up, and the industry declined for the third time. At present potash, iodine, and other chemicals are still being produced from kelps in some countries, but in the United States it is no longer profitable to do so.

The seaweeds utilized in the manufacture of chemicals are the kelps, the fuci, and their related forms. In Europe and Japan they are chiefly species of *Laminaria, Fucus,* and *Sargassum,* and on the Pacific Coast of the United States, the giant kelp, *Macrocystis pyrifera,* is the most important one.

Fertilizer and stockfeeds. Whole or chopped seaweeds are widely utilized as fertilizers in countries with extensive coast lines, especially China, Japan, Great Britain, and France. These plants contain not only large quantities of soluble potassium compounds and some nitrogenous compounds, but also bulky organic substances which slowly decay in the soil and form humus. The seaweeds used for manures are generally the large ones, especially members of the genera *Laminaria, Fucus,* and *Sargassum.* In Ireland the demand for seaweed manure is so great that one species, *Fucus vesiculosus,* is specially cultivated to meet the demand. In most cases the seaweeds are collected by farmers in the vicinity of the seacoast and applied by them directly to their own fields. Because of its high potash content, seaweed fertilizer is especially beneficial to root crops such as the potato, sweet potato, and beet. As a fertilizer it is fully as valuable as barnyard manure and has the added advantage of being free from weed seeds and fungus spores.

In certain European countries herds pasturing along the seashore graze on living fuci and other algae exposed at low tide. Seaweeds are gathered, boiled, and mixed with meal, and the resulting mixture fed to horses, pigs, and cattle. In California a kelp company prepared a kelp meal from *Macrocystis,* which was found to be a good food supplement for chickens, foxes, and cattle.

THE SEAWEED INDUSTRY IN CALIFORNIA

California has one of the richest coasts in the world—not only in fish resources but also in marine vegetation. The value of the relatively young seaweed industry in this State is already worth at least two million dollars annually, with only a rather small portion of the potential natural production being utilized.

Agar. This extract is the only one from seaweed sources that has received the attention of the War Production Board. Two months after the attack on Pearl Harbor, this commodity was frozen and its uses restricted to the preparation of bacteriological culture media.

In California agar is extracted from the local seaweed, *Gelidium cartilagineum,* which occurs in commercially harvestable quanti-

ties from Point Conception southward. It is a reddish-purple, fern-like alga which grows on rocks from the low tide mark to a depth of thirty or more feet. It grows best in turbulent waters and in regions where there is a continuous swell Although it may attain a height of four or more feet, it is harvestable when about one and one-half feet tall Practically all the commercial weeds are harvested with a diving rig, only a small quantity being gathered with a long-handled rake. The diver wears a complete diving outfit and, crawling over the rocks, pulls the weed off by hand. In a good working day of about six diving hours, an experienced diver can get as much as a ton of the wet weed. Generally, however, the amount harvested per day is between 1,000 and 1,500 pounds. There are not many working days in a year, since during the winter months the ocean is usually too rough for the diver to work Even in the summer, there may be only two days out of three when the water is calm enough for this rather strenuous and precarious work. The weed is dried in the sun and baled, but it is not bleached, as is the practice in Japan.

The California method of processing agar is much more modern than the traditional Japanese procedure, but the basic principle is the same in both: agar is soluble in boiling water but not in cold water. Thus, when crude agar gel is frozen and later thawed, the cold water draining away will carry with it the soluble salts, pigments, and various impurities. Agar may also be precipitated by alcohol and other chemicals, although this method has not yet been applied commercially. The freezing-thawing method seems still to be the cheapest one, although technologists are working on improved methods.

The first agar factory in the Western Hemisphere appeared in Glendale (formerly Tropico), California, about 1920. Strange to say, the person who founded an industry which eventually freed the United States from dependence upon Japanese agar, was a Japanese, Chokichi Matsuoka. He processed the weeds by the traditional Japanese procedure, with some minor modifications. The company apparently was not financially successful and was later sold to a group of native Americans. It remained for a Californian, the late John Becker, to modernize the agar manufacturing method. Now there are agar factories at San Diego, South Pasadena, Los Angeles, Orange, and Whittier, all in southern California. In the largest of these factories, producing about one-third of the quantity of agar previously imported by the United States from Japan, the process is as follows: The agarphyte is soaked in cleaning vats and then the agar is dissolved from the plants by hot water in pressure cookers (Fig 9). The hot solution passes through filter presses to tubs where it gels upon cooling. The resulting gel is crushed and is poured down into cans in the freezing room (Fig. 10) The frozen gel is thawed and the cold water, in which impurities are dissolved, is separated from the agar particles in rotary vacuum filters. As the resulting agar flakes still carry about 90 per cent water, they are delivered to stack driers (cylinders three stories high) in which they are dried by an ascending stream of hot air.

Algin. The giant kelp, *Macrocystis pyrifera,* provided the United States with potash during the last war. It is now producing another important article, algin, which is likewise helping the war effort. While algin is also being produced on the East Coast, from *Laminaria,* more than 70 per cent of the total U. S. production comes from southern California.

Macrocystis is truly a giant kelp, growing to a length of over one hundred feet. It attaches to rocks at a depth of ten to seventy-five feet in regions where there is a continuous swell. Thanks to the private and government investigations conducted during and shortly before the first World War, we have a better knowledge of this seaweed than of any other useful form. At present the harvesting of kelp is highly mechanized and is effected by a mowing machine, cutting three to four feet below the surface, and carrying as much as three hundred tons in a single load. The operation is carried out in calm weather throughout the year.

The method of extracting algin is based on the fact that alginic acid itself is insoluble whereas its sodium salt is readily soluble in water. The fresh kelp is therefore digested with soda, which reacts with the acid to form

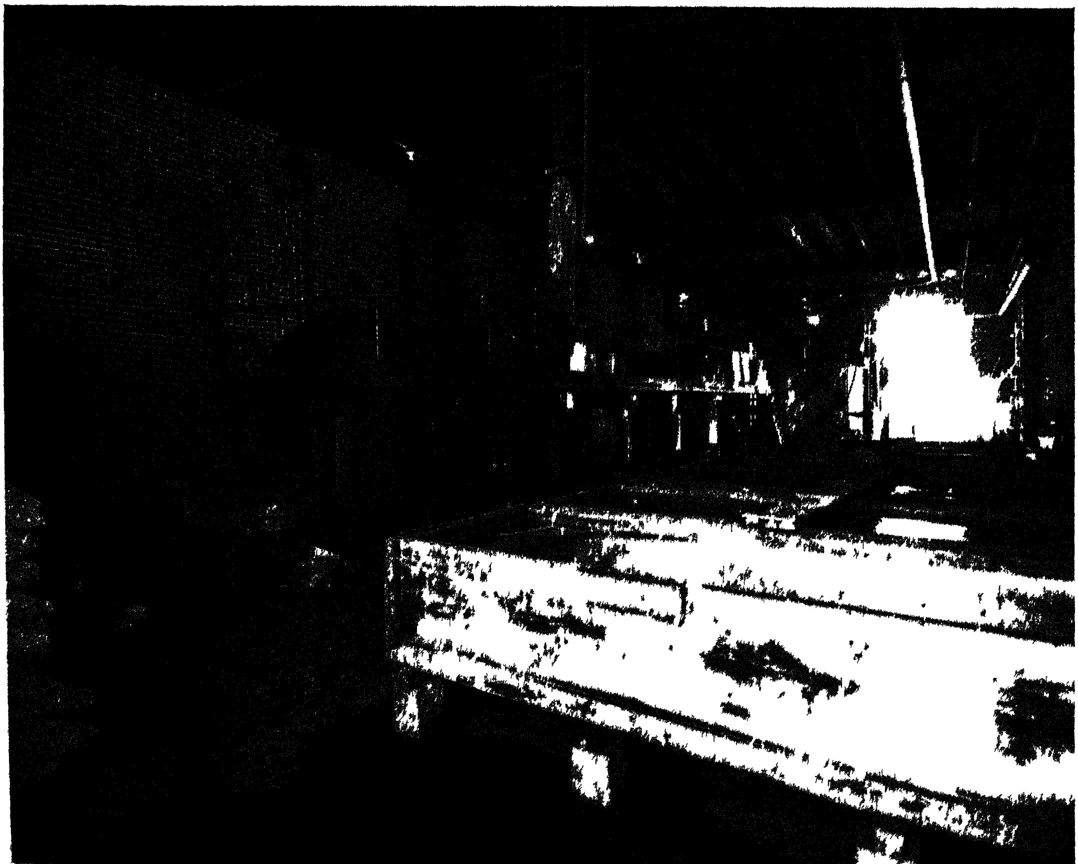
the soluble sodium alginate. This is filtered from the pulpy residue, and the subsequent addition of an acid precipitates the insoluble alginic acid. A wide variety of metallic and organic salts of alginic acid are marketed.

Porphyra. The only seaweed which has been utilized directly for food in any quantity in California is the perforated purple laver, botanically *Porphyra perforata.* This is a very common seaweed along the entire California coast. Being an annual, it generally appears in winter and spring and continues to grow until early summer. It grows on rocks in rather sheltered places to the limit of high water.

It was reported that 300,000 pounds of dried *Porphyra* were harvested in 1929 by white men and Indians in northern California and by Chinese in central and southern California. Chinese buyers distributed the products to Chinese stores or exported them to China, especially to Hong Kong and Canton. The Chinese harvesters usually came to the *Porphyra* grounds in the fall and burned, with driftwood, the rocks on which they expected their seaweed crop to grow. By early spring these rocks were densely covered with the laver. In harvesting, the seaweed is merely pulled from the rock by hand and is dried in the sun in the form of rectangular sheets.

The Future of the California Seaweed Industry

It has previously been remarked that the amount of useful seaweeds now being harvested in California is only a small fraction of the total natural production. The greatest obstacle to the development of the local



Courtesy of the American Agar and Chemical Company

FIG. 9. INITIAL TREATMENT OF AGARPHYTES FOR PRODUCTION OF AGAR

SOAKING VATS ARE ON THE RIGHT, PRESSURE COOKERS ARE ON THE LEFT, AND FILTER PRESS IS IN THE REAR.

Courtesy of the American Agar and Chemical Company

FIG. 10. ROOM IN WHICH PARTIALLY PURIFIED AGAR-GEL IS FROZEN

THE CANS FILLED WITH CRUSHED AGAR-GEL ARE LOWERED INTO THE COLD BRINE BENEATH THE SLATTED FLOOR.

seaweed industry lies in the high cost of the raw material, because of the necessity of using human labor in the harvesting. Thanks to the efforts of scientists, especially the late Professors W. A. Setchell and N. L. Gardner of the University of California, we have a good knowledge of the kinds of seaweeds that grow on the Pacific coast, but we have neglected other phases of research on seaweeds, especially the relationship between the seaweeds and their chemical and physical environments, the life history of the red seaweeds, the development and growth of the useful species, and the technology of seaweed products. Consequently, we are still unprepared to build a great seaweed industry in California.

For several reasons the processing of kelp undoubtedly has a more promising future than that of other seaweeds: First, we have a better knowledge of the essential biology of *Macrocystis* than of any other useful seaweed. Second, scientists have estimated that we could harvest annually more than 30 million tons of fresh kelp south of Point Conception. As the kelp companies in southern California are probably harvesting only about fifty thousand tons annually, the supply of the raw material for the future expansion of the industry is practically unlimited. Third, the demand for algin as a stabilizer is continuously increasing, and new uses for it are also being found. Finally, the harvesting of kelp has been highly mechanized, thus reducing greatly the cost of the raw material.

The agar industry faces a much more difficult future: First, we still know very little about the growth, reproduction, physiology, and life history of the agarphyte, *Gelidium cartilagineum*. Second, the harvesting of this seaweed must be effected entirely by manual labor and below the surface of the

sea. Furthermore, it is not easy to collect because it generally grows in small patches and usually clings to the ragged edges of rocks. A practical mechanical device to harvest it has not yet been invented, although thousands of dollars have been spent in the attempt. As a result, the cost of fresh *Gelidium* is almost fifty times that of fresh kelp. Third, the threat of Japanese competition after the war makes American interests reluctant to invest money in an industry which may collapse in the face of cheap foreign imports. In some past years it has been reported that the agarphyte harvested in California cost almost as much as the finished agar imported from Japan. Fourth, although California agar is much more carefully and scientifically manufactured than the Japanese product, our present manufacturing method still needs numerous improvements. For instance, a significant portion of the agar now remains in the discarded pulp after cooking—a portion which should be recovered.

During the present war emergency there is no Japanese competition, and the government is buying agar at three dollars a pound. After the war, however, conditions may be very different. If the California industry cannot produce a cheaper agar, it will be doomed to failure. In fact, in its twenty-three years of existence the American agar industry has persisted only through periodic injections of new capital and has several times been at a standstill. Fortunately, through the persistent effort of a few persons like the late John Becker, and also because of the high quality of the local product, California had, at the outbreak of the war, a skeleton agar industry. In the interest of future national defense, the agar industry should be encouraged to attain a permanent status. This can be achieved in part by research on the biology of the principal agarphyte, *Gelidium cartilagineum*, and also by research on the technology of manufacture. Another possible solution of the problem is to find other agar-bearing seaweeds which can be gathered at a lower cost than *Gelidium*. Recently it was found that *Gracilaria confervoides*, one of the seaweeds used in agar manufacture in other countries, occurs in large quantity in bays in southern California. From this plant, a much cheaper agar can be produced, because of the relatively low cost of harvesting it. The Gracilaria-agar seems to be poorer in quality than the Gelidium-agar; however, it should be useful as a substitute for the latter in certain fields. South Africa and Australia are already producing agar-gel from *Gracilaria*. England is also reported to be trying to make her own agar from a local seaweed, probably the same plant. On the East Coast, some Gracilaria-agar has already been produced and offered for sale. Utilization of the West Coast *Gracilaria* will greatly increase the local production of agar and may also help to reduce its cost.

When Americans have come to realize that some seaweeds, *Porphyra* for instance, are palatable and just as delicious as some of the vegetables, the seaweed food industry will certainly have a promising future. At present the consumption of *Porphyra* as food in this country is limited to Orientals, especially the Chinese. "Wild" purple laver is abundant on the coast of California. Moreover, this plant can always be cultivated without much difficulty and on a large scale if the natural supply is not sufficient to satisfy the demand.

Besides *Macrocystis, Gelidium, Gracilaria,* and *Porphyra,* California has many other kinds of potentially useful seaweeds. For instance, there are several species of *Gigartina* and *Iridophycus* which contain a seaweed gum very similar to, and probably identical with, carrageenin extracted from Irish moss. Large quantities of these medium-sized seaweeds are found in various places on the Pacific Coast, especially in the latitude of Monterey. I once gathered from the rocks about eighty pounds of *Gigartina corymbifera* in only fifteen minutes at low tide.

In order to achieve a successful, permanent seaweed industry in California it is highly desirable to carry on further research on the biology and life history of the useful species, on the ways and means of utilizing them, on the harvesting methods, and on the technology of extracting the unique substances present in these marine crops.

PROTEINS: THE MACHINES OF LIFE

By M. F. PERUTZ

On a recent visit to the United States I was greatly impressed by the proficiency which Americans display at designing, constructing, and operating all kinds of mechanical devices. The stranger is led to the conviction that Americans are born with an understanding of machines; indeed, it would not have surprised me in the least to see a baby driving its own perambulator.

However, much as I admired the ingenuity of American machines, I could not help thinking how very simple even the most complex man-made machines are if we compare them with the machines that make man or any other living organism.

One of the most startling developments of modern America is mass production. Yet mass production has merely copied the workings of life by developing a much higher degree of specialization than had been known before. If we try to draw an analogy between a factory and a living organism, then the brain may be compared to the administrative offices combined with the main switchboard, or the heart to the engine room.

As in a large factory, each of these organs is itself a complex department, and the tasks it has to perform are distributed among a great number of specialists. In the last resort it is found that any particular physiological function is fulfilled by chemical compounds or molecules specially designed for the purpose. Such specialist molecules may consist of atoms numbering between ten and a hundred thousand, and each kind is usually capable of doing one job and one job only.

Alcoholic fermentation by yeast may be quoted as an example of the extreme to which specialization is carried in nature. I learned at school that yeast contains an enzyme called zymase, which turns glucose into alcohol and carbon dioxide. In the meantime biochemists have discovered that in its transformation to alcohol the glucose passes through at least a dozen intermediate stages, and that each chemical reaction leading from one stage to the next is induced by a different enzyme which specializes on this reaction only. Thus the supposedly simple enzyme has become a complex system of different enzyme molecules, each doing its own job.

The great majority of these specialist molecules are proteins; that is to say, they belong to the group of substances which make up the bulk of the animal body. Bones, muscle, skin, hair, all consist mainly of protein. Proteins are capable of providing the living organism with mechanical strength and protective cover and of fulfilling a vast variety of chemical functions.

Although the constitution of this most interesting and versatile group of chemical compounds has been the subject of inquiry amongst biochemists and physiologists for many decades, our knowledge of them is still in a rudimentary stage. The trouble is that they are so large; much larger than the molecules which chemists usually handle. The latter consist of some tens of atoms or at the most of some hundred, whereas the smallest known protein molecule contains nearly a thousand atoms and some of the giant ones may contain several hundred thousand. The ordinary methods of chemical analysis break down when we try to apply them to molecules of such gigantic size; new methods had to be developed to cope with problems of this unprecedented complexity, giving rise to a new branch of science, the physical chemistry of proteins.

The first great protein chemist was Emil Fischer. He discovered that the fundamental constituents of all proteins—the bricks, as it were—are the same and belong to a group of substances called amino acids. Figure 1 shows examples of two different amino acids; actually there are twenty-three different kinds of amino acids known with certainty at present. Strictly speaking, two of them are *imino* acids, but that recondite chemical difference may here be disregarded. Each amino acid contains at least one amino (basic) and one carboxyl (acidic) group which enable it to form salts with both acids and bases.

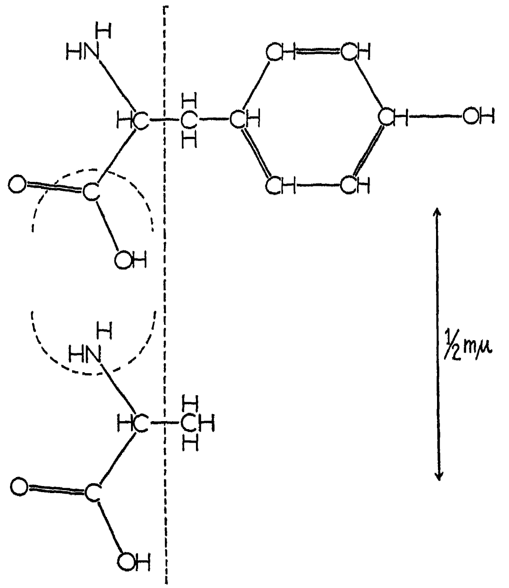


FIG. 1. TWO AMINO ACIDS
TYROSINE ABOVE; ALANINE BELOW. SAME GROUPS ON LEFT OF LINE; DIFFERENT SIDE CHAINS ON THE RIGHT.

The twenty-three different kinds are distinguished by the nature of their side chains which are attached to the second carbon atom. Fischer put forth the bold hypothesis that proteins consist of amino acids joined end to end to form chains, the joint being made between the acidic group of one amino acid and the basic group of the neighboring one (Fig. 2). This kind of joint was known as a "peptide bond," and Fischer therefore called the chains built up by joining amino acids in this way polypeptide chains.

He succeeded in producing such chains artificially and demonstrated that the synthetic product had many properties in common with natural proteins. Since the time when Fischer did his fundamental work at the beginning of the century, his results have been confirmed and extended in many directions, particularly by Bergmann at the Rockefeller Institute for Medical Research in New York.

Despite the relatively small number of fundamental constituents, polypeptide chains show such versatility that it took scientists a long time to realize all their possibilities. Let us consider these for a moment. In a chain containing a total of twenty-three amino acids, each of them of a different type, these acids can be arranged in 13×10^{21} different ways. If the chain contains several hundred amino acids, then the possible number of different arrangements of the twenty-three types is hardly conceivable.

This is not all. Quite apart from the possibilities of chemical variation, a tremendous variety of geometrical configurations enable proteins to fulfill almost any mechanical or chemical function in the organism. Polypeptide chains may form straight bundles or coil up in one plane or fold up in space in an almost infinite variety of different ways. Each of these configurations will give rise to different physical and chemical properties.

The simplest configuration which polypeptide chains can assume is a bundle of straight chains. If the chains are very long, the bundles will tend to form fibers. Natural silk, for example, consists of bundles of straight polypeptide chains (Fig. 3). The silkworm prefabricates these chains in soluble form in his silk glands before spinning them into a cocoon of strongly resistant fibers, in order to protect himself during pupation.

In other fibers, where elasticity rather than rigid strength is required, folded chains may be bundled together into fibers. Stretching unfolds these chains which act like coiled springs and fold up again as soon as the fiber is released. Animal hair, feathers, nails, horns, and such are all built on this pattern.

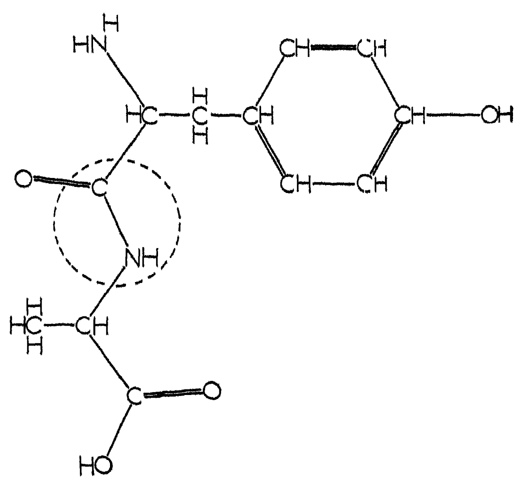


FIG. 2. AMINO ACIDS LINKED
TYROSINE AND ALANINE ARE NOW JOINED BY MEANS OF A PEPTIDE BOND, SHOWN INSIDE THE DOTTED CIRCLE.

If hair is heated excessively, the elasticity of the molecular springs is destroyed, and the hair becomes permanently set; a property which hairdressers discovered long before the scientists and which they used for providing ladies with permanent waves. Elastic bundles of polypeptide chains also play a most important part in muscle; this consists mainly of a fibrous protein, called myosin, which actually expands and contracts with every twitch of the muscle.

It has been mentioned that polypeptide chains can also form two-dimensional fabrics or networks. Such networks probably occur in the membranes of cells, but so far little is known about them.

The most important proteins are the globular ones where the polypeptide chains are arranged in the form of a three-dimensional network. Their part in the organism cannot be too highly stressed. It is almost true to say that plant and animal life consists of the sum total of the activities of globular protein molecules. They are as vital to amoebas as they are to the existence of mammals. They are the machines of the living organism. In this article I shall endeavor to show some of the tasks which they perform and, as far as our very limited knowledge permits, describe the mechanism by which they do it.

The variety of properties which globular proteins may exhibit is as endless as the number of configurations which a polypeptide chain can assume. Nevertheless there are some characteristics which are common to many proteins and one of these is solubility. Most of the globular proteins are more readily soluble than the fibrous ones; this is not surprising, for to be effective as enzymes or carriers of oxygen, proteins have to be dissolved in the body fluids. This solubility is easily lost by heating, which coagulates them and destroys their biological activity.

The boiling of an egg, for example, not only coagulates the proteins in the egg, but it also makes it impossible to hatch it. The difference between an intact protein and a boiled one seems to be that in the former the polypeptide chains are arranged in a definite pattern and form molecules of specific weights and dimensions, whereas the boiled proteins merely consist of tangles of chains of indefinite length and shape.

We can picture the process of coagulation if we imagine that heat makes the neatly ordered chains wriggle so violently that they unfold and get entangled with their neighbors in the process. Once the orderly configuration of the chains is lost, we cannot restore it, even if we try to disentangle them by redissolving the coagulated proteins in strong acid.

Protein molecules are much too small to be seen under any microscope; their size and shape, therefore, have to be inferred indirectly. The weight of the smallest known protein molecule, secretin, is about 5,000 times greater than the weight of a hydrogen atom'; that of the largest one, haemocyanin, nearly 7,000,000 times greater. If we regard the molecules as spheres, then their diameters range between 2.3 and 25 mμ (mμ means a millimicron and is equal to a millionth of a millimeter).

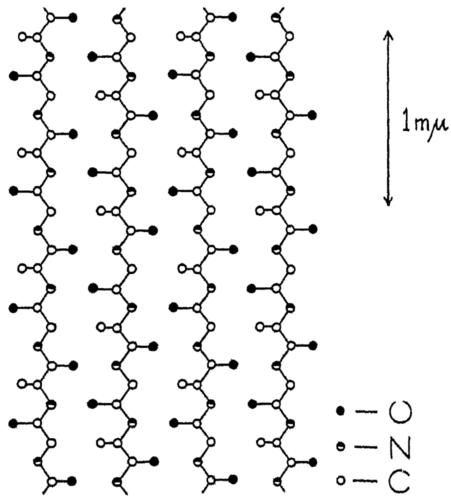


FIG. 3. STRUCTURE OF SILK FIBER
BUNDLE OF STRAIGHT POLYPEPTIDE CHAINS AS IT PROBABLY OCCURS IN FIBERS OF NATURAL SILK.

In order to give a better idea of the smallness of a protein molecule, we may compare its diameter with that of an ordinary pin's head. The number of protein molecules of the smallest size that could be accommodated in the volume of a pin's head is about the same as the number of pins' heads that could

FIG. 4. HAEMOGLOBIN CRYSTALS
PHOTOMICROGRAPH OF CRYSTALS FROM BLOOD. THEY MAY RANGE IN LENGTH FROM 0.01 TO 0.5 MILLIMETER.

be packed into a sphere of the diameter of La Guardia Airfield in New York.

Many proteins form crystals as beautifully shaped and as transparent as snowflakes. A protein can in fact be identified by the shape of its crystals. This was shown very effectively by two Americans, Reichert and Brown, who photographed the crystals of haemoglobin from nearly all vertebrates and found that their shape varied from species to species (Fig. 4). The difference between crystal types becomes greater the further removed two species are from each other.

The different crystal types merely express the individual features which distinguish protein molecules from each other. What these features are can only be surmised at the moment, but the discovery of the individuality of proteins, or specificity as it is usually called, has given rise to most of the spectacular developments in medicine. The practice of vaccinating or inoculating people against certain diseases derives its scientific background from the specific reactions of proteins.

In 1796 Edward Jenner, a physician in Berkeley, Gloucestershire, made a vital experiment. He had noticed that dairymaids whose hands showed small pustules from cowpox remained unaffected while an epidemic of smallpox swept the countryside. Jenner tried to transfer the dairymaids' resistance against smallpox by inoculating a boy in the arm from the pustule of a young woman who was infected by her master's cow. The experiment was successful, and the boy remained immune against the smallpox.

Today, we vaccinate babies with cowpox soon after they are born; as a result smallpox, once a dreaded disease killing hundreds of thousands every year, has practically vanished from the civilized world, and many other once menacing infections have been rendered harmless by timely vaccination.

How does vaccination protect? To vaccinate against a certain disease small quantities of either dead bacteria or bacterial extracts of a nonvirulent form of the disease carried are usually injected. As soon as these foreign particles invade the organism, an intricate system of defence is set in motion, and a special blood protein called gamma-globulin becomes sensitized against the intruders. If, after a lapse of time, the same intruders invade the blood stream in more formidable numbers, then the sensitized globulin molecules will at once set upon them and herd them together into impotent clots which can easily be eliminated from the system.

A remarkable feature of the sensitized globulin molecules is their specificity. They will only react with the particular type of intruder against which they were sensitized and with no other. If the sensitized globulin is so specific, how is it then that vaccination with cowpox will protect us against smallpox? It so happens that the cowpox virus is such a very close relation of the smallpox virus that the globulin sensitized against the one is equally effective against the other. Hence infection of a man with the harmless cowpox virus renders him immune against its deadly relative, the smallpox.

Great advances in understanding the mechanism of immunity reactions were recently made by Pauling and his collaborators at the California Institute of Technology. Pauling postulated that during the sensitizing of an animal against an intruder, certain chemically active groups on the surface of the intruding particle act as templates against which the globulin molecules rearrange their polypeptide chains, so as to fit

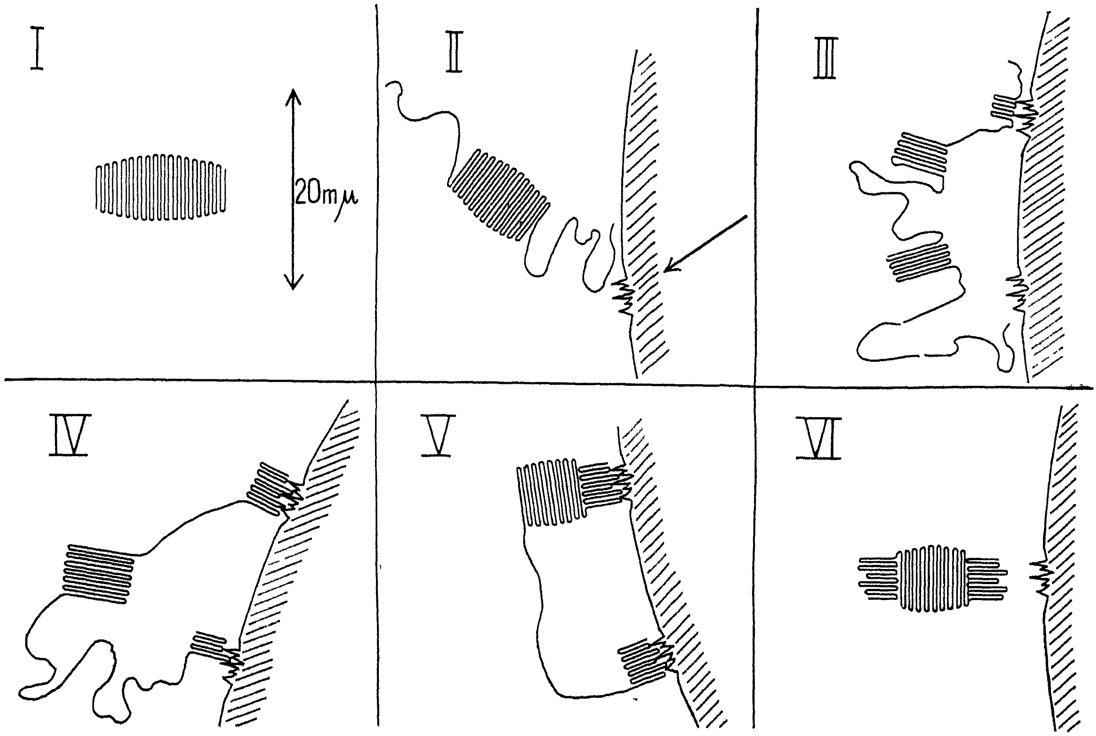


FIG. 5. THEORY OF FORMATION OF A SENSITIZED GLOBULIN MOLECULE
I, NORMALLY FOLDED GLOBULIN MOLECULE. II, MOLECULE UNFOLDS AS IT APPROACHES A PNEUMOCOCCUS. III, IV, V, FITTING ENDS OF THE MOLECULE TO ACTIVE GROUPS ON COCCUS. VI, SENSITIZED MOLECULE.

those templates as a key fits a lock. There is one qualification to be added to this picture; while only one end of a key fits a lock, both ends of a globulin molecule must adapt themselves to the templates on the intruder's surface if they are to fulfill their function effectively (Fig. 5).

Now supposing the animal has been sensitized against typhus bacilli, and those bacilli later invade its blood stream, how do the globulin molecules contrive to clot them? Each bacillus will attract hundreds of sensitized globulin molecules, which will attach themselves to its surface with one of their activated ends while trying to hook on to a second bacillus with the other. The globulins which already cling to the second bacillus will in their turn try to capture a third and so on until thousands of bacilli are clotted together in a helpless mass (Fig. 6).

Pauling followed up his ingenious theory by showing that globulin can be sensitized outside the animal's body. He prepared a solution of globulin from ox blood and let it stand at an elevated temperature together with a suspension of pneumococci, the bacilli which cause pneumonia. After several days the cocci were filtered off again. By then the globulin molecules in solution had evidently become sensitized, because experiments showed that they were now able to clot much larger numbers of pneumococci than had been contained in the original suspension.

Pauling concludes that the application of moderate heat accelerated the thermal motion of the polypeptide chains of the globulin molecules, thereby enabling them to change their configuration so as to fit onto the active groups on the surface of the pneumococci. In this way a slight change in the arrangement of the polypeptide chains transformed inactive globulin molecules into protectors against pneumonia.

Vaccination helps to reinforce the body's defence against particular diseases. Infection with many kinds of common bacteria and viruses, however, occurs almost every day, and their penetration into the blood stream in small quantities induces the pro-

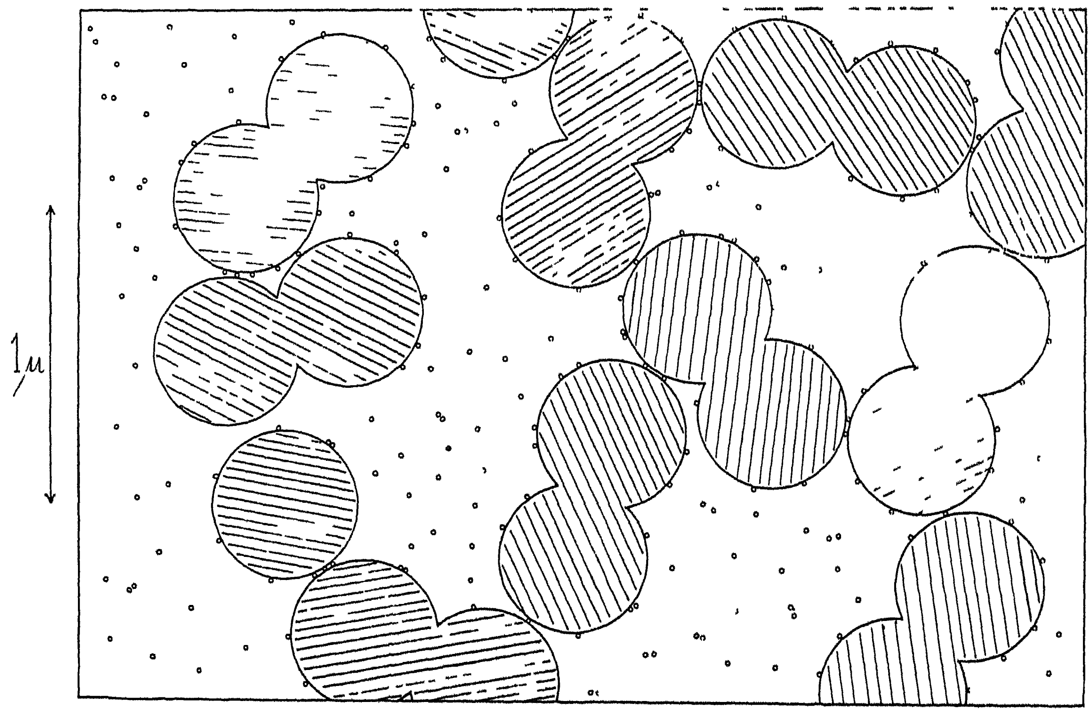


FIG. 6. CLOTTING OF PNEUMOCOCCI BY GLOBULINS
THE LARGE CROSSHATCHED BODIES REPRESENT BACTERIA; THE SMALL CIRCLES SHOW GLOBULIN MOLECULES.

duction of sensitized globulin molecules which keep the healthy organism immune against infection.

Every animal needs oxygen for the combustion of food which supplies it with energy. The combustion takes place in the tissues, and the oxygen has to come from the air. Since only one-fifth of the air consists of oxygen the organism needs some machinery to separate it from nitrogen and to transport it to the tissues. A certain amount of air reaches the tissues by diffusion through the skin and by transportation of dissolved air in the blood, but neither of these processes provides oxygen in sufficient amounts. Animals therefore have to have oxygen carriers—molecules which can combine with oxygen and set it free again wherever it is needed. In vertebrates the oxygen carriers are molecules of haemoglobin, a solution of which is enclosed in the red blood corpuscles.

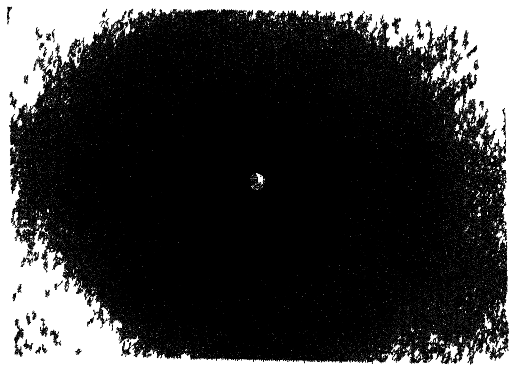


FIG. 7. X-RAY DIFFRACTION PHOTOGRAPH
OBTAINED BY THE ROTATION OF A SMALL CRYSTAL OF HAEMOGLOBIN IN A NARROW BEAM OF X-RAYS.

The haemoglobin molecule is one of the most remarkable chemical substances known. It consists of four red pigment groups known as haems and a colorless protein residue called globin. At the center of each of the four haems is an iron atom which can combine with one oxygen molecule. Thus each haemoglobin molecule can transport four molecules of oxygen.

The combination with oxygen takes place in the blood vessels which permeate the lungs from where the oxygen-rich or arterial blood is pumped to the tissues; here the oxygen is taken over by other proteins while the oxygen-free or venous blood returns to the lungs. In a test tube. shaking of a haemo-

globin solution with air produces oxygenation and turns it bright red; connection with a suction pump sets the oxygen free again and changes the color of the solution to purple.

There is nothing remarkable about that to the layman's eye. On the other hand, the chemist whose concern it is to manufacture oxygen from air cannot fail to admire Nature's ingenuity, seeing that no one ever succeeded in producing a chemical substance that can be made to combine with oxygen and give it off again by using no stronger agent than a small change in pressure.

If the chemical engineer wants to make oxygen, he has first to liquefy the air by cooling it to $-200°$ C. under high pressure and then to subject the liquid air to fractional distillation. If haemoglobin could be used instead, the horsepower required to produce one cubic foot of oxygen would be reduced to a fraction of the present requirements, in addition to the saving of much costly machinery. Unfortunately, haemoglobin, once it is removed from the animal body, is too unstable a substance to be used on a factory scale.

Haemoglobin is typical of the specificity which is so characteristic a feature of proteins. Experiments show that any change in the haemoglobin molecule, however slight, either modifies or destroys its capacity for reversible combination with oxygen. Haem by itself will not act as an oxygen carrier, nor will it do so if it is linked to any protein other than globin. If globin, on the other hand, is linked to pigments which differ from haem in nothing more than a trifling detail, it fails to transform them into oxygen carriers.

Sir Joseph Barcroft, the famous British physiologist, recently demonstrated how a slight change in its protein component can influence the oxygen affinity of the haemoglobin molecule. Experimenting on the problem of foetal respiration, he made the surprising discovery that the haemoglobins of mother and foetus are not the same.

To explain this it should perhaps be pointed out that, contrary to most people's belief, the mother's blood does not flow through the foetus. The foetus has its own circulatory system which is connected by the umbilical cord to the placenta where it terminates in a multitude of fine capillaries. There the blood of the foetus comes into close contact with the mother's blood which is pumped through the placenta in a similar but entirely separate system of capillaries.

How then does the foetus get its oxygen? Nature's solution is as ingenious as it is simple. The oxygen affinity of the foetal haemoglobin is slightly greater than that of the mother's haemoglobin, which results in the oxygen migrating through the walls of the capillaries from the blood of the mother to that of the foetus. So far as could be ascertained, the only difference between the two haemoglobins lies in their different affinities for oxygen. However, there must be a molecular cause to account for the change in behavior, and in the absence of any difference in chemical composition the explanation is likely to be found in a different folding of the polypeptide chains in the globins of mother and foetus.

Haemoglobin is generally confined to vertebrates and occurs only rarely in other animal groups. A variety of different oxygen carriers has been discovered amongst invertebrates. Snails and crabs, for instance, have blue blood. The blue color is due to an oxygen carrier which contains copper and is called haemocyanin. The great naturalist, Ray Lankester, discovered a marine worm with green blood and called its oxygen carrier chlorocruorin. Both chlorocruorin and haemocyanin are proteins, the latter having the distinction of being the largest molecule found in nature.

If the chemist wants to break down a protein into small fragments or build up a complex organic molecule, he uses high temperature and pressures, strong acids and alkalies, powerful solvents, extreme vacuum, and many other devices. The living organism has to perform the same reactions at 100° F., at atmospheric pressure, and without any solvent other than water. Instead of high pressure cylinders and fractional distillation columns, the organism uses enzymes.

Each enzyme specializes on one particular chemical reaction, which it induces without becoming either changed or used up in the process. Take pepsin, for instance, a gastric

enzyme which splits proteins into subunits of medium size; a pepsin preparation can split many times its own weight of protein without undergoing any perceptible change. Chemists call it a catalyst because it induces a chemical reaction without, apparently, taking part in it.

The variety of enzymes is baffling, as each of the many chemical reactions in nature is induced or catalyzed by an enzyme specially adapted for the purpose. There may be thousands of different enzymes, but rather less than two hundred of them are known and fewer still have been isolated and purified. All those isolated up to date are proteins and most of them are concerned either with the breaking down of food in the digestive tract of animals or with the further degradation of digested food in tissues and cells.

Little is known as yet about the class of enzymes which may one day become the most interesting one—those enzymes which induce the building up of proteins and other molecules from the small fragments which the digested food supplies.

It is highly probable that all chemical reactions which help to build a living organism are catalyzed by enzymes, many of which are still unexplored. Nor is much known about the mechanism by which these substances contrive to induce reactions. Enzyme chemistry, therefore, is still to some extent a virgin field which offers great opportunities for research, despite the impressive volume of work that has already been done.

One of the difficulties of protein research is that the molecules are too small to be observed under a microscope and yet too large for chemical analysis. This state of affairs induced scientists to develop a variety of physical methods which allow us to get a glimpse, at least, of the principal features of the molecules and to measure constants such as their weight, their shape, and their external dimensions.

The weight of protein molecules can be measured by means of the ultracentrifuge, an instrument invented in the early twenties by the Swedish scientist, Svedberg. He puts a protein solution into a small quartz cell which he then spins at the extraordinary rate of 1,000 revolutions per second. He thereby subjects the protein molecules to forces which are nearly a million times stronger than those of gravity.

Why are such tremendous forces needed to weigh protein molecules? The explanation is the same as before: they are too small to be put on a balance and too large to be weighed by the ordinary chemical methods. Svedberg's ultracentrifuge works on the principle that the weight of small particles can be calculated from their rate of sinking in water. If particles are as small as protein molecules, however, then their tendency to move hither and thither under the influence of heat counteracts their tendency to sink, so that they will remain in suspension indefinitely if they are subjected to no stronger force than the gravitation of the earth.

One way to make them sink is to spin the solution so fast that their heat motion is overcome by the powerful pull of the centrifugal field. The rate of sinking is then recorded photographically and used, together with certain other information, to calculate the molecular weight of the protein.

By making it possible for the first time to weigh protein molecules rapidly and accurately, the invention of the ultracentrifuge marked a cornerstone in protein research and has added immeasurably to our knowledge of these vital substances.

Another field of protein physics was opened up by two Cambridge scientists, Bernal and Miss Crowfoot, when they discovered that protein crystals can be made to give X-ray diffraction patterns which contain as much detail and are as clearly resolved as the patterns given by ordinary crystals such as sugar or naphthalene. It should perhaps be explained that the analysis of X-ray diffraction effects from crystals, or X-ray analysis as it is called for short, enables the physicist to work out the submicroscopic structure of matter. At the moment X-ray analysis is the most hopeful line of attack not only for measuring the external dimensions of protein molecules, but also for getting information about the distribution of matter within them.

Figure 7 shows a photograph by the writer of X-ray diffraction from a haemoglobin crystal. From pictures like this it

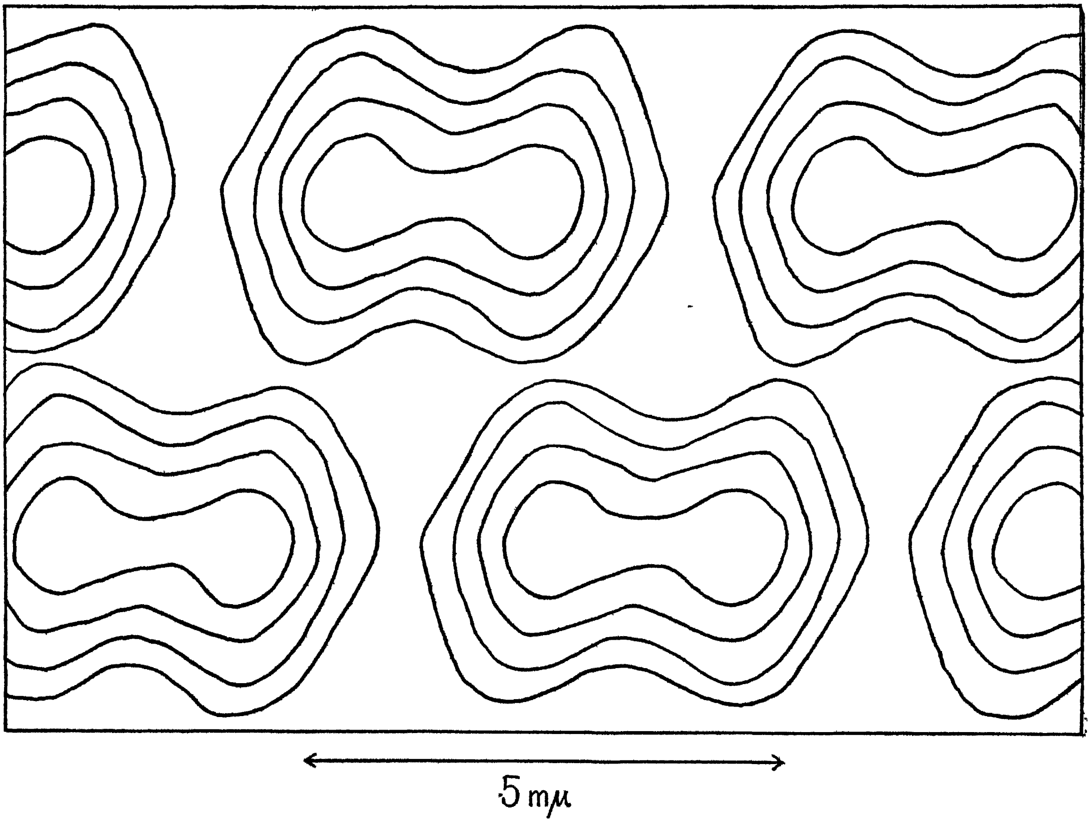


FIG. 8. CONTOURS OF HAEMOGLOBIN MOLECULES
CALCULATED FROM X-RAY ANALYSIS, THE RESULTING PICTURE IS LIKE A POORLY RESOLVED MICROSCOPIC IMAGE.

was found that the haemoglobin molecule resembles an egg-shaped body with a length of 6.4 mμ and an average width of 4.2 mμ. Figure 8 is a contour map calculated directly from an X-ray diffraction photograph and gives an end-on view of the molecules.

X-ray analysis of protein crystals was only just starting on a sufficient scale when war broke out, and many research projects were interrupted. The results so far obtained promise that it will be an important line of advance in the future.

The secret of the extraordinary versatility of proteins undoubtedly lies in their molecular architecture. Their capacity of protecting the organism from infection or of inducing chemical reactions appears to be based on the endless variety of different compositions and shapes which polypeptide chains can assume and which in turn give rise to a multitude of different patterns of chemically active groups on the surface of the protein molecules.

At present the molecular structure of the globular proteins is still unknown. While it is unlikely that any single line of research or any startling new theory will suddenly reveal all that we desire to know, a concerted effort by scientists who specialize in different fields and can attack the problem independently from more than one angle has every chance of success.

There is good hope that before very long new methods of research, together with refinements of existing experimental technique will gradually increase our general knowledge of proteins and lead to a more profound understanding of the micromechanism of Life.

PHYSICAL CHARACTERS OF THE AMERICAN NEGRO

By M. F. ASHLEY MONTAGU

THE American Negro must be regarded as one of the newest types of mankind. He represents the effect of a considerable amount of mixture among different African varieties, American Indians, and whites of every kind —principally whites of British origin. Out of this mixture has come the unique type or ethnic group represented by the American Negro. The type is even yet in process of formation, and all the evidences indicate that while the American Negro occupies, so far as his physical characters are concerned, a position intermediate between the African Negro on the one hand and the white and American Indian on the other, he will, if the social barriers against intermarriage and miscegenation are maintained, tend to stabilize around a type which is rather more Negroid than otherwise. Even so, his physical structure will continue to be characterized by many elements bearing the marks of his white and American Indian ancestry.

The chief visible characters which distinguish the Negro from the white are skin color and the character of the hair. A few other characteristics in which the Negro is popularly held to differ from the white are body odor, size of genitalia, size of brain, and vocal cords.

The results of investigations thus far carried out make possible the following summary of the physical characters of the typical American Negro. It is to be understood that the findings on the characters here cited have been repeatedly confirmed by different investigators working independently of one another, and that the results, unless otherwise stated, are statistically significant. It will be seen that in most of his characters the American Negro presents a blend of, or is intermediate between, African and white.

Compared with old American whites or mixed Europeans, the American Negro's head is slightly longer and narrower, and its height and cranial capacity are less. His hair line is lower on the forehead; his eyes are set wider apart; his nose is broader, shorter, and has a lower bridge; his jaws project further, accentuated by thicker lips; and his external ear is shorter. In body characters, the American Negro's torso is shorter, his arm longer, chest shallower, pelvis narrower and smaller, and leg longer. He is heavier in weight and shorter in stature than the white.

The American Negro's skin contains a greater amount of black pigment than that of whites. His hair is wavy, curly, frizzly, or woolly and is less thickly distributed. His sweat glands occur in greater number.

A large number of characters have been omitted from this summary; some because they have not been proved to differ in Negro and white, others because information is not available, and still others because the available evidence is so unsatisfactory that it requires separate discussion. We may now briefly consider the significance of the summarized differences.

Head. In general, the head of the American Negro is about 2 mm. longer and about 1 mm. narrower than the head of the white. Consonant with this form the elevation of the Negro head is somewhat lower than that of the white by about 5 mm. This difference in the height of the head is probably significantly associated with the very slightly smaller brain of the Negro. The mean cubic capacity of the Negro brain as compared with the white, as determined by Wingate Todd, was 1350.25 c.c. for Negro males and 1391.08 c.c. for white males. The difference is 41 c.c. in favor of white males. Cranial capacity and brain weight are characters which are very variable, and there are very few observations into which the personal factor enters so much as in the determination of these characters. But when all is said and done, Todd's difference of 41 c.c. is probably as reliable and as accurate an estimate on small samples of American Negroes and whites, of similar social status, as it would be possible to obtain. In discussing head size and brain size it is necessary to remember that the American Negro

is some 2 cm. shorter in total stature than the white; while this difference cannot account for the whole of the difference in brain size of the Negro, it probably does account for part of that difference.

It is obvious that, as far as the diameters of the head are concerned, the Negro head tends to be long as compared with the tendency towards reduction in length, and a compensatory increase in breadth and height, in the white. It is known that, within the same ethnic group, broad heads have a somewhat greater cranial capacity than long heads. Reliable evidence is lacking on the relative thickness of the bones of the Negro skull, but if there is any real difference it must be exceedingly slight, and would make, except in aged individuals, very little difference in the cranial capacity. In short, the size of the Negro head is very slightly smaller than that of the white, and different in shape, being long rather than broad. A difference of some 40 c.c. in cranial capacity suggests a very slightly smaller brain volume in the Negro as compared with the white. Actually, a difference of 40 c.c. is so small, falling well within the normal range of variation of the white brain, that it can hardly be regarded as significant from any but a purely statistical point of view.

If the Negro brain is somewhat smaller than that of the white, the difference will be found to be so little that it can hardly be considered in any way significant for the mental functioning of the Negro as compared with the white. Within the limits of normal variation, differences in brain size have about as much relation to intelligence and cultural achievement as differences in body size, and as far as the available evidence goes, that is none. The Negro Kaffirs and Amaxosa of Africa, the Japanese, American Indians, Eskimo, and Polynesians on the average have brains which are larger than those of the average white. On the same grounds as the white proclaims himself superior to the Negro, he should proclaim these peoples superior to himself—thus far, however, there are no evidences that any white man is ever likely to do so. The fact is that the external morphology of the human brain, or the characters of size and weight, have little or nothing to do with its functional capacities; these, on the other hand, must be considered as due to a complex of characters, such as the genetically determined internal (microscopic) structure of the cells and neurones, and the organization to which these are subjected by experience, the abundance of the blood vessels, the character of their walls, and the efficiency of blood drainage.

Upon these matters we have no evidence adequate enough for a definitive judgment beyond the statement that at the present time there exists no evidence in support of the popular belief that significant morphological or functional differences exist between the brain of the Negro and that of the white.

The common stereotype that the Negro's brain or mind stops growing at thirteen is completely false. The oft-repeated statement that the cranial sutures in the Negro unite earlier than do those in other races, "and thus cause a stunting of the Ethiopian intellect shortly after arriving at puberty," can now quite definitely be disposed of as a result of the fundamental studies of Todd and Lyon on suture closure in Negroes and whites; these studies prove that no significant differences in the character of suture closure exists between the two groups.

As far as the growth and development of the skull is concerned, there are no significant differences between Negroes and whites. Differences, however, do exist in the pattern and rate of growth in certain bones of the skull, and these differences are already apparent during fetal development; as Schultz has pointed out, these differences are essentially the same as those which distinguish adult whites from adult Negroes.

Thus Limson found that in Negro fetuses the back of the head was more prominent and convex, and the external protuberance on it more strongly formed than in white fetuses. Limson also found that the dental arch projects further forward, and that the anterior nasal spine is smaller in Negro than in white fetuses. These are precisely the regions of differential growth which Todd and his co-workers have shown to distinguish the adult Negro cranium; namely, a greater expansion of the occipital bone at the back of the head, and a greater forward growth of the upper jaw and dental arch. This dif-

ference in the detailed growth pattern of the jaws has been shown to hold good in Negro fetuses in respect to the premaxillary bone, which tends to lose its independence later than in the white. This fact is significantly correlated, of course, with the somewhat greater projection of the upper jaw in the Negro than in the white. This projection of the upper jaw is not a true *prognathism* similar to that which occurs in the anthropoid apes, for the early arrest in the growth of the brain case and the continued growth of the jaws and dental arches in the apes do not occur in any variety of man. The projection of the upper jaw in the Negro is accentuated, compared with the conditions in the white, because in the latter there is an earlier arrest of growth in the upper jaw than in the Negro. From every point of view the reduction in the size of the upper jaw in whites must be considered unfortunate, for the resulting restrictions of space are responsible for a very large number of disorders, such as failure of development of teeth, or the noneruption, crowding, or rotation of teeth, deflection of the nasal septum, cleft palate, and harelip. The retention of the ability for continued growth by the Negro maxilla as compared with the loss of this ability in whites would here indubitably confer a physical advantage upon the Negro.

The shape of the nose in the Negro is variable, but on the average is a shorter, flatter, and broader nose than that of the average white. It has been cogently suggested that the broad nose and larger nasal passages of the African Negro are adapted to meet the requirements of air breathed at relatively high temperatures, whereas the relatively long, narrow nose of the white is adapted to the breathing of air at relatively low temperatures. A statistical investigation of this problem gives this suggestion a high degree of probability.

Statements to the effect that the Negro nose is more primitive than that of the white are erroneous. For example, Dr. Victor Heiser has recently stated that the Philippine Negritos are true Negroes as "was shown by the one piece cartilage in their spreading noses; all other races have a split cartilage. Even the octaroons show this Negroid test of Negro blood." The fact is that no split cartilage occurs in any monkey, ape, or man, and that there are no significant characters of the nasal cartilages, except those of size, which distinguish the nose of the American Negro from that of the white. The Negro nose merely exhibits a difference in form. There is every reason to believe that the original form of the African Negro's nose persisted in Africa as an adaptively valuable character, and that in the American Negro the form of the nose, while still very variable, presents a form blending those of white, American Indian, and African Negro. The greater the admixture with whites, the more Caucasoid does the form of the nose appear. Even so, there is a marked tendency toward persistence of the broad nose. This, among other characters, has been termed an "entrenched Negro character," that is to say, a character which is said to show relatively great stability under hybridization. Other such features are lip thickness, mouth width, interpupillary distance, and ear height. As for the apparently larger eye of the Negro, this is an illusion resulting from the comparatively smaller angular orbit of the Negro. On the other hand, it has been shown that two of Todd's most dominantly entrenched Negro characters, lip thickness and breadth of nose, very readily undergo change towards the type of the white lip and nose under hybridization. It would seem, however, that an appreciable amount of admixture must usually occur before these two characters actually assume the "ideal" white form.

The slope of the forehead is not significantly different in Negroes from that in whites; its apparent difference is an illusion due to the greater projection (prognathism) of the Negro's upper jaw. The mistaken belief that Negroes have lower foreheads than whites may be attributed even more to the fact that the hair grows lower upon the forehead of the former. Under hybridization this low level of the hair line appears to be one of the first characters to yield.

In African Negroes the chin prominence is not as marked as in whites, but in American Negroes it is intermediate between the condition found in African and white. Undoubtedly it increases with increase in the proportion of white admixture.

Body. Since statements are frequently made which refer to the alleged "apelike" hands of the Negro and his long arms or long legs—as those who make such statements see fit—we may briefy consider these matters here.

The Negro torso is about an inch and a quarter shorter than that of the white, the Negro leg a little less than an inch and a quarter longer. The Negro arm is about an inch longer, the upper arm being relatively shorter and the forearm relatively longer than in the white. As for hand breadth and length, Todd and Lindala found no significant differences in these dimensions, a fact which led these investigators to remark, "It is rather astonishing to find that the 'long narrow hand' of the Negro vanishes on the average." It was considered by these authors that this finding could not be imputed to admixture with whites, since their series gave many evidences of relative purity of strain. Herskovits also failed to find any significant difference in the width of Negro and white hands. While the Negro hand as a whole is not longer than the white's, the fingers appear to be longer. Thus Herskovits found that the middle finger is longer in Negroes than in whites. This, then, would make that portion of the hand in the Negro which extends from the wrist to the base of the fingers shorter than in the white, but this supposition requires confirmation. With respect to the length of the thumb, the present writer has found that the African Negro thumb is about 1.7 mm. shorter in relation to the length of the middle finger than the relative thumb length of the average Englishman. These findings corroborate, in a rather striking manner, the observations of Schultz who found the length of the thumb in relation to the middle finger in adult Negroes to be 1.8 mm. less than in adult whites. In relation to the length of the hand Schultz found that both in Negro fetuses and in adults the thumb was relatively shorter than in whites.

Hence, as far as the upper extremity is concerned, it would appear that every part of it is perfectly proportionate to the other, and that the greater length of the Negro arm may be interpreted as a compensatory adjustment in relation to the shorter torso. As for "apelike" characters of Negro hand or arm, these are entirely lacking, both in the proportions and in the deeper structures.

Unlike the bones of the arms, those of the legs of Negroes are proportionately the same as those of whites, the length of the whole leg being greater. As Todd has put it, "The long shin of the Negro is an illusion of its circumference, as his long foot is an illusion of its flatness." In length and breadth the Negro foot shows no significant differences from the foot of whites, these dimensions being entirely proportional to leg length.

Recent attempts to show that Negro athletes enjoy an unfair advantage over white athletes, owing to the alleged possession of a longer heel bone and longer calf muscles, have been critically examined by W. M. Cobb, who has shown that many of the outstanding Negro athletes have legs and feet which are predominantly white in their characters, and that Negroid physical characters are not in any way significantly associated with Negro athletic ability. In this connection it may be noted that Malafa, in an investigation of the bodily characters of sprinters and nonathletes, carried out on 100 white students from the Grammar Schools of Brno, Czecho-Slovakia, found that long legs were one of the principal characters which distinguish the athletes from the nonathletes. This character constitutes, of course, a selective factor and is not correlated with racial or ethnic characters.

One fact more concerning the Negro foot: the alleged longer heel bone is nonexistent, but both in fetuses and adults it is given an appearance of greater length by a thick layer of subcutaneous fat.

Pelvis. It is frequently stated that the Negro pelvis differs from that of the white in being longer and narrower. This statement is not quite true. The Negro pelvis is smaller in all its dimensions. It is greatly to be doubted whether there is any truth in the common belief that because the Negro female has a narrower pelvis than the white female she is the more likely to experience a less satisfactory termination of a pregnancy produced by a white than by a Negro male; the suggestion here usually being that the rounder-headed white is likely to produce a fetus which will have a larger and a

rounder head than can be safely delivered through a small, narrow pelvis "intended" for the delivery of Negro-fathered children

Caldwell and Moloy, from the obstetrical point of view, have investigated the anthropometric characters of the pelvis of Negro and white females. These investigators find that female pelves may be classified into three types, as follows: (a) the gynecoid, or average female type, which occurs in 42 per cent of Negro and in the same percentage of white females; (b) the android type, more closely approximating the male than the female pelvis, which occurs in 15.7 per cent of Negro females and 32 5 per cent of white females; and (c) the anthropoid type with a long antero-posterior diameter and a relatively narrow transverse diameter, occurring in 40.5 per cent of Negroes, and slightly less than half that percentage in whites.

Obstetrically, the most dangerous form of the pelvis is the android type which occurs with double the frequency among whites that it does among Negroes. The other two types of pelvis present no especial obstetrical difficulties. It therefore seems most improbable that the form of the pelvis plays a more significant role in childbirth in Negroes than in whites.

Davenport and Steggerda "entertain the hypothesis that, in the case of the Black woman who carried a mulatto child *in utero*, her narrow pelvic outlet and the child's large head might offer an important disharmony." In order to test this hypothesis they proceeded to examine the heads of newborn colored and white children. They found that the heads of newborn colored infants were slightly smaller at birth than those of white newborn infants, and it is quite evident from their findings that no disharmonies between pelvic outlet and shape of the head occurred in the Jamaican series examined by them. Data on the pelves were not available to Davenport and Steggerda, but the data which have since appeared render highly improbable a significant disharmony of the kind hypothecated.

Skin color. Skin color is a very complex character and depends upon a multiplicity of factors for its expression. As is well known, every color from black to white occurs among American Negroes. The greater the admixture of white genes, the lighter, as a rule, does the skin appear. It has been found that in the American Negro the percentage of pigmentation increases fairly rapidly until puberty, reaching its maximum at about the age of 15; thereafter it decreases rapidly until about the age of 35 and then decreases very slowly during the remainder of life.

The inheritance of skin color is a cumulative process involving the operation of multiple factors, the individual having the largest number of factors usually showing the character developed to the highest degree. In Negro-white crosses the genes for black pigment are incompletely dominant over those for lighter color, and the first generation is mulatto or intermediate in shade. The offspring of mulattoes, however, exhibit a great variability and gradation of their skin color, from black to white. This is an effect of multiple-factor inheritance, for owing to the large number of factors now present, they are segregated in combinations which are more distributively variable than those that were possible in the original ancestors. This form of blending inheritance is essentially Mendelian. The evidence thus far suggests that there are several pairs of genes conditioning skin color, yielding about a score of genotypes and about ten phenotypes—assuming that the gene pairs have approximately the same effect. Actually a far wider range of phenotypes is observed, suggesting the existence of other modifying genes affecting skin color. Further investigations of a most refined and laborious nature remain to be carried out before the mechanism of the inheritance of skin color is fully understood.

Black children cannot be born to parents one of whom is "pure" white. When a colored infant is born to white parents it is proof positive that both of the parents carry Negro genes. Similarly a Negress with some white genes cannot bear a white child to a "pure" Negro.

Hair. The hair of Negroes is dominantly black, although it may be dark brown, gray brown, light brown, and even red in varying frequencies, the lighter colors occur-

ring more commonly among persons with a half or more of white ancestry. The black color of the hair is one of the most dominantly entrenched of Negro features. On the other hand, hair form is, interestingly enough, one of the most easily modifiable of characters; and while among American Negroes every form of hair from woolly to straight is to be found in a considerable number of gradations, it is clear that under hybridization hair form yields most readily to the influence of new genes. This fact was strikingly brought out in the classic study of Fischer on the hybrids of Hottentot-Dutch ancestry in South Africa; the one group with dominantly woolly hair, and the other with dominantly straight hair. Fischer found that among these Rehobother Bastards woolly hair occurred in 29 per cent, frizzly or wavy hair in 49 per cent, and straight in 22 per cent.

Davenport and Steggerda found that among Jamaicans woolly hair occurred in 100 per cent of blacks, in 86.7 per cent of browns, and 1 per cent of whites. Curly hair occurred in none of the blacks, in 11.4 per cent of browns, and in 30 per cent of whites. Wavy hair did not occur in blacks, but was found in 2 per cent of browns and 30 per cent of whites; and 39.2 per cent of the whites had straight hair.

Hair form in Negro-white crosses varies with degree of admixture. The evidence indicates that distinctively Negroid forms of hair, such as frizzly and woolly, do not appear unless there is at least three-eighths of Negro ancestry in the individual.

The inheritance of hair form in Negro-white crosses has been studied by Davenport, who found that straight hair is a recessive condition. Wavy or curly hair is a heterozygous condition, so that wavy × wavy yields offspring which is straight, wavy, and curly in the proportion 1:2:1. Curly × curly yields mostly curly; yet 14 per cent of the offspring show straight hair. So it is apparent that some curly-haired parents carry the gene for straight hair as a recessive.

Straight × wavy and straight × curly produce a good many curly offspring. Thus, an analysis of hair form of 428 offspring of Negro-white crosses showed that seventy-five had curlier hair than the more curly parent, while only forty-three had straighter hair than the straighter parent, thus suggesting the general dominance of the curlier condition.

Distribution of hair. It is a common belief that the Negro is less hairy than whites. This belief is well-founded, for the development of his body hair, both in thickness and in distribution, is considerably less than in the white. Recent investigations suggest that a reduction in the number of hair follicles has occurred in the Negro, and also a deficiency in the growth of individual hairs. This would appear to be the most plausible explanation of the relative glabrousness of the American Negro. Investigation of the facial hair of Negroes and whites reveal that there is no difference in the actual number of hairs, but that the average thickness of the facial hairs in the Negro is less than that in the white; also the hairs of Negro women are somewhat shorter than those of white women.

In the Negro, as compared with the white, the general tendency towards reduction in the amount and distribution of hair has proceeded furthest, as is evidenced by the reduction in the number of hair follicles on the fingers and toes, and the arms and hands of Negroes. It is highly probable that the genetic mechanisms here operative are much the same as for skin color and hair form, with the presence of multiple factors and the consequent segregation of intermediate forms.

Sweat glands and body odor. One of the most popularly entrenched beliefs concerning the Negro is that he possesses a unique and particularly objectionable body odor. This odor depends upon a very large number of factors. Human sweat consists of the secretions of the sebaceous glands and the sweat glands proper. Among the known constituents of sweat are water, sodium chloride, phosphates of the alkaline earths, urea, creatinine, ethereal sulphates of phenol and skatoxyl, neutral fat, fatty acids, cholesterol, albumin, and iron. Depending upon the amount of these substances present, the odor of the sweat will vary in the same individual from time to time, and under different environmental and dietary conditions.

Upon this subject no really adequate studies have been made. We now know only that body odor varies from individual to individual within the same ethnic group, and that members of different ethnic groups, and even castes or classes, find the odor of members of other ethnic groups and castes or classes distinctly different and frequently objectionable. Klineberg refers to:

> An experimental attempt to throw a little further light on this question . . . in an unpublished study by Lawrence, who collected in test tubes a little of the perspiration of White and Colored students who had just been exercising violently in the gymnasium. These test tubes were then given to a number of White subjects with instructions to rank them in order of pleasantness. The results showed no consistent preference for the White samples; the test tube considered the most pleasant and the one considered the most unpleasant were both taken from Whites.

Klineberg concludes:

> There may be racial differences in body odors, but it is important first to rule out the factors referred to above, particularly the factor of diet, before a final conclusion is reached. It is obvious that cleanliness is also a factor of importance. In any case, the phenomenon of adaptation enters to remove any special unpleasantness arising from the presence of a strange group.

Comparative studies of the physiology and chemistry of the sweat of Negroes and whites do not exist, but several studies have been made of the sweat glands in Negroes and whites from the anatomical standpoint. Clark and Lhamon found that the hands and feet of Negroes were more abundantly supplied with exocrine glands (glands which originate from the skin) than were those of whites. Glaser, in an investigation of the sweat glands in one Bantu Negro and in one European, found that "the regional distribution of the sweat glands in the Negro agrees closely with that usually given for the European. . . . In the great majority of regions compared, however, the Bantu has more sweat glands than the European, and this is probably of considerable value to him in resisting extremes of heat." Homma, in a study of the apocrine glands (glands which originate from a hair follicle) of ten Negroes and twelve whites, found that they occurred three times more frequently in the Negroes than in the whites, and that while such glands never occurred in the breasts of whites they were sometimes to be found in the breasts of the Negroes.

Thus, it is evident that if Negroes possess a greater number of sweat glands than whites, heat regulation under high temperatures would be more efficiently performed in them than in whites; and it is also possible that if there is any difference in the odor of their sweat, it probably represents not a difference in kind, but in degree or intensity, owing to the cumulative action of the number of glands involved.

Blood. The belief that Negro blood differs from white blood is another common stereotype. Here, again, there is no ground for the belief whatsoever. In all the constituents of the blood, such as hemoglobin, red cells, agglutinogens, and agglutinins, the blood of Negroes is the same as that of whites. The same blood groups A, B, AB, O, and the blood types N and M and the Rhesus factor occur among Negroes as among whites, so that transfusions of blood from Negroes to whites, and vice versa, are perfectly safe in every way. As would be expected, the only differences found are in the distribution of the frequencies with which the various blood groups occur in Negro and white.

Even when these facts are understood, objections are sometimes raised to the effect that the transfusion of Negro blood into a white might make the white somewhat Negroid. This is, of course, sheer nonsense and merely reflects the persistence of the age-old superstition that the blood is the carrier of the hereditary traits of the individual, and that the latter are transmitted by blood. This is not so. Blood is the nutritive material of the body, through the medium of which many other substances are conveyed to the tissues, but none of these when injected into another individual are in the slightest degree capable of altering his hereditary or physical traits. It is highly desirable that the term "blood" as a synonym for "heredity," "ancestry," or "race" be completely eliminated from common, as it has been from scientific, usage.

INTERDEPENDENCE IN PLANT AND ANIMAL EVOLUTION*

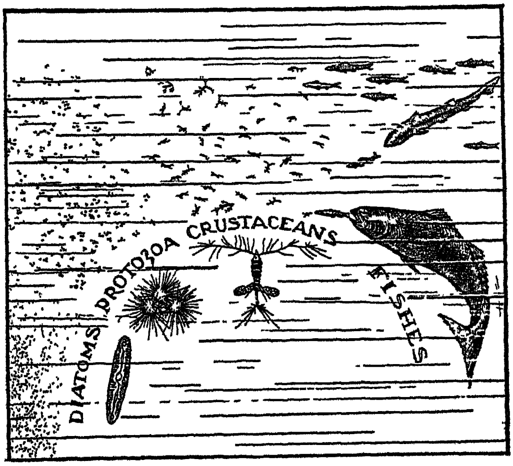
By ALFRED GUNDERSEN and GEORGE T. HASTINGS

THAT animals depend on plants for their food is well known, but this is only part of the story. In the course of its evolution the plant world has greatly influenced the animal world, and, vice versa, the animal world has influenced the plant world in a number of important respects. The extensive subjects of plant and animal evolution are naturally taken up separately, but there are clearly vital connections between them. We have attempted to call attention briefly to what we believe to be varied aspects of one comprehensive whole.

ALGAE AND FISHES

Algae, protozoa, copepods, and fishes form the principal food chain of the ocean. Sea environment is more nearly uniform than land environment. In the water everything weighs less, temperatures are more even, and there can be no water shortage as there often is on land. As a result of this uniformity, water life is less diversified than land life. Fringing continents and islands nearly everywhere is a zone of seaweeds, mostly brown in cold and temperate climates, mostly red in warm climates and at greater depths. In this shore zone sea life is the most varied and abundant, attached to the bottom, creeping, floating, or swimming. In the middle of the oceans organisms must be floating or swimming. The conditions of the open sea, in particular the conditions at the time of storms, are such as to require plant life to be of very small size and very strongly built. Such are the characteristics of the innumerable diatoms, the primary food supply of the sea, the "grass" of the ocean.

Diatoms are one-celled algae, enclosed in two valves, one fitting over the other like the lid on a box. There are thousands of species, many of great beauty, with symmetrical designs on their valves. They grow and multiply rapidly in sunlight a few feet below the surface of the water, and as a result of their photosynthesis vast quantities of oxygen are given off. Diatoms average less than one two-hundredths of an inch in diameter; their numbers are enormous. They furnish food for the slightly larger but less numerous protozoa. Therefore the size and the number of diatoms must influence the size



FOOD CHAIN OF THE SEA[1]

and number of protozoa. A very abundant form of protozoa is *Globigerina*, one of the foraminifera, whose tiny "skeletons," like the myriads of diatom "shells," have settled to make great deposits on the ocean bottom.

Both diatoms and protozoa are eaten by the slender and numerous crustaceans, the copepods. One copepod has been estimated to eat 100,000 diatoms in a day. The balance between plant and animal populations is a constantly shifting one. Nearly all young fish live on the small crustaceans. A herring, the most abundant fish in the ocean, takes thousands for a meal. In turn the herring may be eaten by cod, often a half dozen herring being found in the stomach of one codfish. They are also eaten by mackerel and other fish and by sea gulls. In the oceans of the tropics, heat-loving bacteria reduce the number of diatoms, and, as a re-

* Brooklyn Botanic Garden Contributions, No. 101.

[1] All sketches by Maud H. Purdy.

sult, the fish population there is reduced. The variation in the number of young fish in different years probably depends largely on the spring appearance of diatoms at the time of the hatching of fish eggs. An interval between the time the tiny young fish need food and the appearance of diatoms must result in great mortality among the fish.

Facts of structure and of development of living forms suggest that land life was preceded by water life. This is confirmed by fossils from the early periods: the Pre-cambrian, Cambrian, and Ordovician included only water forms, such as algae, foraminifera, sponges, corals, echinoderms, mollusks, and trilobites.

Diatom deposits are abundant from the Triassic to the present. For example, forty feet of diatom shells underlie Richmond, Virginia. What plants were in the sea before that time? Were there diatom ancestors without shells and less abundant? The teleosts or modern bony fishes began in the Jurassic with the great sea reptiles. Possibly the earlier sharks and ganoid fishes were present in only relatively small numbers. In Cenozoic times mammals came into the sea: whales, seals, walrus, and manatees.

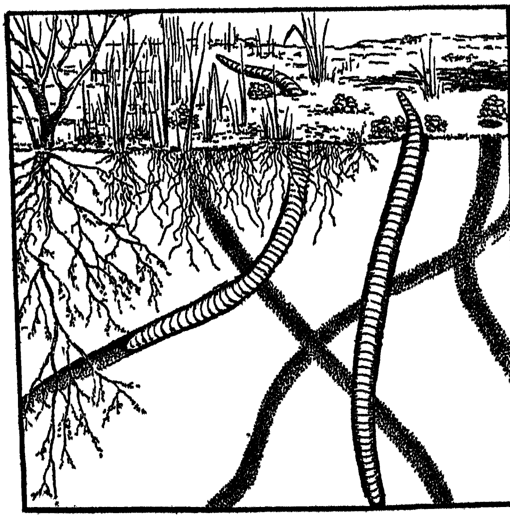
It is suggestive that the sequence of fossils of long ago, algae and protozoa preceding arthropods and these preceding vertebrates, is also the sequence of the food chain of today. Food had to come first: only then could come the successive groups of animals in definite order. In the sea we have dependence on diatoms rather than interdependence. Without the animals, the diatoms need not be different; without the diatoms, the animals could not exist.

Roots and Worms

Soil life seems to be in various ways intermediate between water life and land life. For example, the group of fishes called dipnoi live partly in mud but are to some extent adapted to land life. Land plants and land vertebrates appeared about Silurian times, perhaps four hundred million years ago. Algae most likely were the first plants also on land. Lichens, also probably very early land plants, are a good example of vital interdependence between algae and fungi. Lichens, liverworts, and the fossil *Rhynia* may suggest different lines of development of very early land plants. They are all of small size, like algae they take little or no material from the substratum, and they have no true roots.

But roots characterize all larger plants like ferns and seed-bearing plants. They require soil containing some degree of moisture, in the case of some desert plants growing down fifty feet to get it. Roots usually have many slender branches, covered with myriads of root hairs. These root hairs, constantly renewed, enable plants to take up water and mineral solutions in quantity. Soil is composed of minute fragments of rocks, usually surrounded by films of water and air pockets. There is also organic material, humus, which is important for retaining moisture. In the case of large plants, roots have also the important function of anchoring them securely.

Many animals, especially earthworms, influence the character of the soil. These worms are almost universally distributed, except in deserts; also there are none on oceanic islands, since they are intolerant of salt water. They respond to changes in moisture, in temperature, and in organic content of the soil. Earthworms eat soil particles, digest the organic matter, and deposit the remainder near their holes, with the result that in the long run the soil is



ROOTS AND WORMS IN THE SOIL

changed physically and chemically and becomes better adapted to support vegetation.

Gilbert White wrote in 1777, "A good monography about worms would open up a large and new field in natural history. . . . Vegetation would proceed but lamely without them." About a century later Darwin wrote, "the plow is one of the most ancient and valuable of man's inventions, but long before he existed the land was in fact regularly plowed, and still continues to be plowed by earthworms. It may be doubted whether there are many other animals which have played such an important part in the history of the world as these lowly organized creatures." Different and much smaller worms, the nematodes, are extremely abundant and to some extent supplement the function of earthworms, except that their food is mostly the underground parts of living plants.

Many eggs of insects are laid and hatched underground. Larvae are, so to speak, the worm stage of insects, and feed largely on roots. In some cases, as the Japanese beetle, the feeding of larvae on roots causes wide destruction. Ants and beetles, in particular carrion beetles, and, in tropical climates, termites, have important parts in soil making. Rodents, moles, and other animals make underground burrows for safety and for winter protection. Among plants, fungi and bacteria take essential parts in maintaining soil fertility. All soil organisms contribute to the organic content and to the mixing of the soil. Their excrements and ultimately their dead bodies became part of it. Thus, with exceptions, the soil activities of animals are beneficial to plants and have influenced their growth and development to an extent not generally realized.

Earthworms are Oligochaeta or few-bristle worms and are not known as fossils, but their relatives, the Polychaeta or many-bristle marine-worms, have early fossil representation. So we believe that earthworms or their relatives have been active since early times.

Cycads and Reptiles

Cycads and reptiles, or more specifically cycadeoids and dinosaurs, were the most abundant plants and animals during a large part of the Mesozoic era. Both groups were forerunners of important succeeding ones. Ginkgo and conifers were larger than cycadeoids, but less common. Fleshy seeds such as those of cycads and ginkgo imply adaptation to animals; they long preceded fleshy fruits. Some of the dinosaurs doubtless had a part in the distribution of Mesozoic seeds.

Marine iguanas feeding on seaweeds show that reptiles can live on primitive plant food. The quiescence of reptiles as compared with the activity of mammals suggests that their food requirements are smaller. As flowering plants are not definitely known before the Cretaceous period, their distribution before that time is likely to have been limited. Gymnosperms and more primitive plants, including water plants and sea vegetation, must have supplied the basic food requirements of early Mesozoic times.

All seed-bearing plants have two sizes of spores and the small spore must in some way be brought to the large spore; that is, pollination must occur. Living gymnosperms (cycads, conifers, and their relatives) are all wind-pollinated, and there is no reason to suppose that extinct gymnosperms (seed ferns, cordaites, and cycadeoids) differed in this respect. Wind-pollination is effective where many plants of one kind are somewhat near together, so that they present a fairly large surface for the wind-blown pollen. This is the case usually with conifer forests, with poplars and birches in the north, and

SEAWEED, FOOD OF MARINE IGUANAS

with oaks and hickories in middle temperate regions. In the tropics, where we now have a very great variety of species, wind-pollination is not effective. It requires the activity of an insect to bring pollen from one flower to a similar one some distance away.

The cycadeoids had one character different from other gymnosperms; namely, small and large spores on the same cone. In this they were like flowering plants, but their carpels were still open. One step more and they would have had flowers.

In the warm and moist Carboniferous period there were many thousands of species of plants and animals. From the succeeding cold Permian period only a few hundred species are known. In the milder Triassic period the early dinosaurs were few and small. In the Jurassic came the very large Brontosaurus and Diplodocus, living half submerged. The teeth and the claws of the dinosaurs sharply differentiate the many herbivorous from the relatively few carnivorous kinds.

During the Cretaceous period the relative importance of the great groups of plants changed; cycads began to decline in numbers and kinds and have continued to decrease so that today but a small remnant survive. At the same time flowering plants increased until by the end of the period the tree and shrub flora was not greatly dissimilar from that of today. The variety of plants resulted in variety of food and a great increase in the kinds of dinosaurs. But towards the close of the period dinosaurs began to decrease and ended in total disappearance. According to Barnum Brown, "Plant-eating dinosaurs were restricted in their feeding habits to certain types of vegetation. When, through regional elevation towards the close of the Cretaceous period, lakes and swamps were drained, and plant-life changed or became scarce, plant-eaters died out locally and the carnivores went with them." It has also been suggested that the extinction of dinosaurs may have been connected with the spread of the smaller but more intelligent mammals.

Flowers and Insects

Flowers and insects furnish the best known example of plant and animal interdependence. Koelreuter, Sprengel, Darwin, and Hermann Müller studied pollination. Sprengel's famous "The Secret of Nature in the Form and Fertilization of Flowers Discovered" was published in 1793. Gymnosperms are all wind-pollinated and there is no reason to think there was any other kind of pollination up to the coming of flowering plants. A number of the flowering plants also are wind-pollinated, such as the plane tree, sweet gum, elm, oak, walnut, and poplar and, among herbaceous plants, all grasses, sedges, and rushes. Plants pollinated by wind produce pollen in very large quantities, while they have relatively few ovules. Wind-pollination requires a large amount of pollen because so much is blown away and never reaches its destination. Individual wind-pollinated flowers are usually small, inconspicuous, odorless, and nectarless, with pollen and ovules in separate flowers. Living cycads are dioecious; conifers are mostly monoecious. Among wind-pollinated flowering plants staminate flowers are often in pendulous catkins, adapted to sway in the wind, while pistillate flowers have broad lobed or feathery stigmas.

Cycadeoids had dicotyledonous embryos and in most cases stamens and carpels on the same cone. Such presence of stamens and ovules near together would be a prerequisite for insect fertilization; if they were

POLLINATION BY BEES AND BUTTERFLIES

apart, insects would not go from one to the other and the needed cross-fertilization would not be effected. According to Arber and Parkin's widely accepted theory of the origin of flowering plants, following Wieland's discoveries, angiospermy is a method of protecting ovules from insect visitors. They suggest that the broad angiosperm leaf came much later than the angiosperm flower. Magnolia, morphologically the most primitive angiosperm, is the nearest to the cycadeoids. Today we see that beetles crawl on gymnosperms and eat pollen; long ago insects doubtless were eating cycadeoid pollen; the first cross-pollination by insects would be incidental and occasional.

Magnolia flowers are large, single, open, regular, with flower parts separate, with abundant pollen, without nectar, color in part white, greenish-white, or yellowish. Such are believed to be the characteristics of primitive flowers. It is probable that wind-pollinated trees, such as birch, oak, and walnut, formerly had separate carpels, making them in this respect more like magnolia. Advanced flower structures are the opposite of those mentioned: small flowers, in dense inflorescences, carpels united into a pistil, petals united into a sympetalous, irregular corolla. The more specialized a flower the fewer the species of insects that visit it. In a few cases an insect is adapted for only a single species of flower.

Stages of adaptation of insects to flower visits are believed to have been somewhat as follows: (1) Insects largely with biting mouth parts, lacking structures adapting them to flower visits, but which occasionally visit flowers: dragonflies, grasshoppers, many flies, and beetles. In this connection it is of interest that Carboniferous insects were morphologically unsuited for entering flowers. (2) Insects partly adapted to flower visits: short tongued bees and some flies. (3) Fully adapted flower visitors, with both structure and habits aiding them in getting nectar, while at the same time they effect cross-pollination: long-tongued bees, butterflies, and hawk-moths. Corresponding to this group is the very large variety of flower adaptations which can only be explained in connection with their insect pollination. In addition, some insects cause definite injury to flowers: ants, aphids, bugs, many beetles, and the caterpillar stage of many moths and butterflies.

As we see today that food and food selection plays such an important part in the lives of insects, it is natural to believe that their evolution has been influenced by past changes in food or ways of getting it. Trilobites lived through the early geological periods and vanished. But we have their myriad relatives: copepods in the sea, insects on land. "Bees have played the chief part in the evolution of flowers," wrote Hermann Müller in 1873. And we cannot doubt that flowers have played a large part in the evolution of bees and other insects.

Angiosperms and Birds

Long ago a small number of primitive birds were able to live among a vegetation of cycads and conifers. But today broad-leaved forest trees, fruiting shrubs and herbs, and multitudes of birds belong together. The broad leaves and more succulent shoots of flowering plants, and especially their fruits, make them far better sources of food than gymnosperms. Flowers, by their fragrance and color, announce to insects when they are ready to have their pollen transferred; similarly fruits, by their fragrance and changing color, announce to birds and

BIRDS FEEDING ON SEEDS AND FRUITS

other animals when they are ready to have their seeds transported. Numerous fruits have been greatly changed by human selection. But before man was on the scene, birds and other animals had food preferences, and the fruits selected by them were gradually changed and had the best chance of being distributed and thus of survival. Birds, if they have abundant food, eat what they prefer, otherwise what they can get. They eat both dry and fleshy seeds and fruits, as well as vast numbers of insects. Birds' bills suggest the nature of their principal food: finches, which eat hard seeds, have heavy conical bills, fruit-eaters, such as orioles, have sharp pointed bills. In the cross-bills the tips of the bills are effective for extracting seeds from cones. Seeking larvae, the woodpecker uses its bill to bore holes in bark, while large birds of prey, wading and swimming birds, and insect-feeders, such as swallows, all have bills adapted to their kind of food.

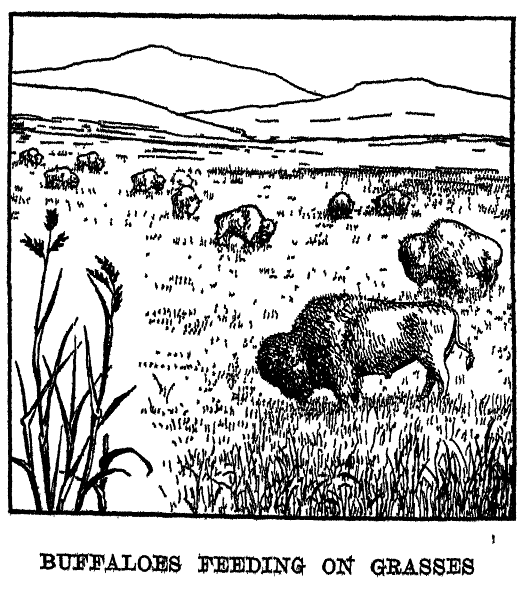
Numerous seeds pass unharmed through the alimentary canal of birds, which are the most effective of all animals in the long distance distribution of seeds. With the increase and spread of flowering plants in the Cretaceous period, the food supply for animals was greatly increased. At the same time birds perfected their powers of flight and took a greater part in seed distribution. More angiosperms, more insects, more birds. But birds probably did not assume anything like their present importance until Cenozoic times. Plants also play an important part in bird life by providing shelter. Nearly all use plant material in building nests. Most small birds nest in trees and bushes, while many ground-nesting birds conceal their nests in clumps of grass or in low bushes. Small birds find safety among foliage where large birds cannot follow.

Carboniferous trees had no annual rings, implying an even climate. In trees of the Cretaceous period annual rings and deciduous leaves indicate a climate with seasons. Warm blood was at first probably an adaptation to winter seasons, beginning some time in the Mesozoic. Birds and mammals carry, so to speak, summer climate inside their feathers and furs. Warm blood is closely connected with more heart chambers, more effective blood circulation, greater activity, and greater need of food.

Fossil records indicate that one branch of reptiles developed into birds, another branch into mammals. The "living fossil," the Australian duckbill, is intermediate between birds and mammals. Both groups were probably tree-living at first. The first birds could fly very little; the first mammals were very small. The earliest known bird is the famous Archaeopteryx from the Jurassic period in Bavaria. Because it had feathers and wings, it was a bird, but it must have been a poor flyer. It had claws on the wings, teeth in sockets, and a long tail with vertebrae to the tip; these were its inheritance from reptilian days. From their teeth it has been supposed that these and Cretaceous birds lived largely on fish, but it would seem reasonable that the tree-living ancestors of birds, like those of mammals, were insectivorous and also used the seeds of cycadeoids and other plant food.

GRASSES AND HERBIVORA

Grasses are the main food of the herbivorous animals. Grasslands cover large areas of the earth, but where moisture and heat are sufficient, forests grow. In the temperate zone rainfall is slight in the interior of continents; these regions are too dry for forests. Grasses cover the extensive, nearly level regions called prairies in North America,



BUFFALOES FEEDING ON GRASSES

llanos in South America, steppes in Russia and Asia. Grasses were long believed to be primitive angiosperms, but are now more generally considered as a specialized group. Monocotyledons, such as lilies, rushes, and sedges, have typically three-parted flowers, which was doubtless the ancestral type of flower of Monocotyledons. Among the grasses, bamboos have a three-parted perianth with six or more stamens: most other grasses have a much reduced two-parted perianth with only three stamens. The early grasses were probably tall forest plants somewhat like bamboos, adapted to a warm and moist climate. The conditions of prairie life are very different; here entirely different and more specialized grasses thrive.

Plants generally grow at the end of the stem and its branches. Grass leaves consist of a sheath at the base and a narrow blade; their growth is not at the tip but near the sheath. Cutting with a lawnmower has a tendency to eliminate plants other than grasses; grazing by herbivora has a similar effect. Grasses are adapted to having their leaves cut off, while other plants are not. Continued cropping causes no injury to grasses, rather it stimulates their growth, and at the same time they are fertilized by the resultant animal dung. Grazing animals by their specialized teeth and digestive system are adapted to feeding on grasses. It is as if grasses and herbivora, through long periods, gradually became adjusted to each other; the same as flowers and insects. A few started it; they had an advantage, and many followed. When the growth of grasses is ended by cold or dry weather, grass leaves dry from the tip; they become hay and so can continue to feed herbivora. Persistent dense leaves and roots of grasses form the characteristic sod, unfavorable to the growth of other plants. Spreading by roots, or tillering, is a mode of reproduction of grasses which is aided by the hoofs of ungulates. The small seeds of grasses are readily transported by the wind.

So long as dinosaurs dominated, ground mammals had little chance to spread. Berry has pointed out that with increase of flowering plants there would naturally be an increase in the number of insects and an increase in the number of primitive insectivorous mammals. About the same time of, or shortly after the extinction of dinosaurs, mammals acquired an important structural improvement, beyond the marsupial stage, in the development of a placenta, which enabled the young to grow more fully before birth. With abundant food from flowering plants, placental mammals rapidly evolved along varied lines into tree-living, herbivorous, carnivorous, and aquatic groups.

The forest-dwelling ancestors of ungulates showed little indication of what their descendants would become. They developed along two lines, the odd-toed from which came our horses and their relatives, and the much larger even-toed group that developed deer, antelopes, sheep, and cattle. By the end of the Eocene period the principal large groups of mammals were in existence. In several cases the fossil history is very complete; for example, those of horses and elephants. In the Eocene the ancestors of these two groups were not very different, both about the size of a fox. Both lines gradually increased in size, some side lines leaving no descendants. The small ancestral horses had simple teeth; they were adapted to browsing in woodlands and groves rather than to grazing. The change to feeding on grasses and to life on the plains was accompanied by change of teeth. Greater speed was needed for safety and with this went the change from five-toed to one-toed hoofs. Elephants found safety along a different line in their tusks and great size. With the great number of herbivora, there came to be room also for smaller numbers of carnivora: a few lions feeding on many zebras; a few wolves feeding on many reindeer.

Forests and Primates

In temperate regions nut-bearing trees and squirrels depend upon each other. The squirrel's habit of burying nuts is often equivalent to planting them. The fruits of tropical forest trees grow mainly in the upper parts of the branches, and can be reached by few animals other than birds and the diversified tree-living mammals, the primates. In the Old World tropics the large fruit-eating bats, called flying foxes,

ORANG-UTAN EATING DURIAN FRUITS

doubtless have a part in seed distribution. But the primates are the principal fruit-eaters and seed distributors of tropical and subtropical regions.

We know from fossils that many mammals were much smaller in former periods, and this applies to primates also. Fossil primates are rare: a few monkeys and apes are from the late Cenozoic periods; lemurs also from the Eocene. Evolution within the order Primates is to some extent seen in fossils, but is also clearly suggested by the living groups; namely, lemurs, tarsius, marmosets, American monkeys, Old World monkeys, anthropoid apes, and man. Size seems to increase approximately with the accumulation of specialized characters. Tarsius, with enormous owl-like eyes, and marmosets are the smallest, man and gorilla the largest of the primates. Although primates are advanced in brain development, in several other characters they are primitive. As compared with carnivora, herbivora, or rodents, their teeth are primitive. Hands and feet with five digits is also a primitive character. Increasing adaptations to life in trees and increasing intelligence are specialized characters. Carnivora generally have multiple births, but among herbivora and primates a single young is the rule. That is about all the herbivora can defend, or that tree dwellers can manage at a time. Nearly all primates have only two milk glands.

Early mammals are known to have been small; they were probably insectivorous, tree-living marsupials. The opossum, only American marsupial, in many ways suggests primitive mammals. Lemurs resemble insectivora; several of them have marsupial characteristics.

Monkeys have smaller jaws and nasal cavities than lemurs. These characters of the higher primates have reduced the effectiveness of the sense of smell, but have improved vision. In lemurs the eyes are directed sideways as in most mammals and in lower animals, but in tarsius and in the higher primates they are directed forward. Thus attention may be given to the same object with both eyes; that is, they have stereoscopic vision with ability to judge distances—very necessary in tree life. Keen vision, a partly upright position, and increased use of hands have a definite relation to food habits, for monkeys see rather than smell what they are eating. They are far better able than other mammals to select deliberately the fruits which they prefer; that means usually the larger ones or the more fleshy ones. And they have been selecting them for a long time.

American monkeys are smaller than those of Asia and Africa; they are more strictly tree-living. Annonas, sapodilla, and Brazil nuts are eaten by American monkeys as well as by man; mango, banana, litchi, citrus fruits, and many others by Old World monkeys. Baboons and macaques have largely reverted to ground life, living in nearly treeless regions. They eat roots and tubers, the pith of aloes, insects, and ostrich eggs and they often devastate orchards.

The anthropoid apes are larger than monkeys and have no external tail. About ten species of gibbon live in southeastern Asia and adjacent islands. The orang-utan lives in Borneo and Sumatra. Wallace wrote that "their food consists almost exclusively of fruits, with occasional leaves, buds and young shoots. They waste and destroy more than they eat, so there is a continual rain of rejected portions below the tree where they are feeding. The durian is a special favorite. The orang is the strongest animal in the jungle." It is interesting that the

durian has approximately the same distribution as the orang-utan. In mid-Tertiary times the durian may have been a good deal smaller and less juicy, and so with other fruits. The gorilla and chimpanzee are African. The full grown gorilla is a ground dweller and eats large quantities of umbelliferous roots.

The primates nearly all live in tropical climates, though a few monkeys live in the Himalayas and northeastward where snow occasionally falls. The special characteristics of primates are connected with their life in trees, where they have a relatively secure food supply. Their greater safety as compared with animals on the ground has given them some degree of leisure. Hand and brain developed together and resulted in an intelligence in which the higher primates surpass all other animals.

Plants and Animals

"Classification instead of being simply a means of separating forms, has become a method of studying affinities, and tracing the phylogenies of groups of organisms," wrote L. M. Underwood nearly fifty years ago. Just what are the principal groups of plants and animals? The answer has been a changing one, as we gradually have learned about the course of evolution. The highest groups of organisms such as flowering plants and vertebrates differ from one another in obvious ways. But the lowest groups are not sharply separate; for example, flagellatae are on the border line between plants and animals. Life forms seem to be united at the base, like the letter V, except that the plant part is far larger in bulk than the animal part. Perhaps we may think of plants as two divergent lines. Thus we have: green plants, fungi, and animals. Fungi have neither chlorophyll nor mobility, while green plants have chlorophyll and animals have mobility. With the ability to move, animals have developed a nervous system and special sense organs, not needed by plants. Green plants use light to build up organic materials from inorganic ones; fungi and animals cannot do this. Plants are stationary or have at most limited mobility of certain parts; animals have the ability to move, at least during part of their lives. The higher plants need locomotion on two occasions in their lives; namely, in the transfer of pollen and in the distribution of seeds. Just what do we mean when we say plants are alive? Their interests are not ours, but they do have remarkably sensitive relations to moisture, to gravity, and to wind; and especially they have a sensitiveness to light far surpassing that of animals. Roots spread out in the soil to get water and its mineral solutions; leaves spread out in the air to get light and carbon dioxide.

Green plants need light for energy with which to make their own food; animals use the food which plants make. The forms of animal groups seem to a large extent to depend on their different ways of getting food. The earliest life forms may have been so simple as to be neither plants nor animals. They may have utilized inorganic compounds as sources of energy and as material for growth, as some bacteria do today. Or it is possible that the action of light may have been associated with the earliest organic life. Once light-using organisms had come, they built up energy-storing carbohydrates and at the same time set oxygen free. Then the stage was set for other life forms that could use these organic foods and the oxygen.

To some extent plants and animals have evolved in similar directions. For example, they have changed from small to large size, with some exceptions. At first plants and animals had soft bodies; later they acquired hard parts. Among the early organisms there was slight provision for the next generation, but among the higher groups this is increasingly important. The great step from water life to land life was taken by both plants and animals about Silurian times, and changes of form became necessary. Plants had to acquire roots and strong stems and leaves. Seeds came very early, apparently in the Devonian period; flowers and fruits ages later. Among animals the fins and airbladder of fishes were transformed to become the legs and lungs of amphibians. In time amphibians became reptiles, and two branches of reptiles became birds and mammals.

"There is another side to evolution so ob-

vious that it is often overlooked, the tendency to link lines together in vital interrelations," wrote J. Arthur Thomson. Animals may eat other animals, but the first link in the food chain is always green plants. Sea-living animals are ultimately dependent almost entirely on diatoms. On land, interdependence develops in connection with the increasing differences between plants and animals. Worms and plants with roots occupy the soil together and have long influenced each other. For ages pollen was transferred only by the wind. When insects became pollinators, the consequences in the development of flowering plants were far-reaching. The spread of flowering plants meant many more insects and more birds. More insects meant more of the small insectivorous mammals. Then came varied groups of larger and specialized mammals, with plant and animal interdependence along new lines, leading up to that between man and food-producing plants. Thus the dependence of the two great worlds of life on each other throws light on successive stages of organic evolution.

IRONY*

An arid daylight shines along the beach
Dried to a grey monotony of tone,
And stranded jelly-fish melt soft upon
The sun-baked pebbles, far beyond their reach
Sparkles a wet, reviving sea. Here bleach
The skeletons of fishes, every bone
Polished and stark, like traceries of stone,
The joints and knuckles hardened each to each.
And they are dead while waiting for the sea,
The moon-pursuing sea, to come again.
Their hearts are blown away on the hot breeze.
Only the shells and stones can wait to be
Washed bright. For living things, who suffer pain,
May not endure till time can bring them ease.

—AMY LOWELL

* From *Sword Blades and Poppy Seeds.* Reprinted at the suggestion of Professor Arnold Dresden, Swarthmore College.

SCIENCE ON THE MARCH

THE NEW CYCLE OF SUNSPOTS

The early months of 1944 have seen the lowest record of sunspot numbers for over a decade, indicating that we are now passing the so-called minimum of solar activity. However, the new solar cycle is now under way; for before the period of actual minimum sunspot activity has occurred, the first spots of the new coming activity invariably appear.

The new spots are distinguished from the last spots of the old cycle in two ways: first, the former appear at high latitudes, usually 40° or more from the sun's equator; second, the magnetic fields of the new groups have a polarity opposite to that of similarly situated spots of the old cycle.

The first group of sunspots identified as belonging to the forthcoming cycle was observed on May 16, 1943. Its magnetic polarity was definitely determined by the Mt. Wilson observers as opposite from that of the old sunspot groups. The new sunspot group appeared on the southern hemisphere of the sun at a mean latitude exceeding 40° from the solar equator. While there is some uncertainty involved in predicting the exact time of the next sunspot maximum, one may confidently forecast increasing numbers of these solar disturbances in the next four or five years, to be followed by gradual decline.

The generally accepted average duration of a sunspot cycle is 11.3 years, but the actual interval between maxima or between minima may vary from nine to seventeen years. The interval between maxima of the last few cycles has been definitely less than the average interval. The last maximum, occurring in the middle of the year 1937, followed the previous maximum of 1928 by only nine years.

Interest in the solar cycle has been much more acute of late because of the importance of the relation between the occurrences of sunspots and radio reception. The ionization of the upper atmosphere, frequently referred to as the "radio ceiling," definitely increases with the advance of the sunspot cycle. The ability to forecast wavelengths and frequencies for best radio communication between various parts of the world rests in no small measure upon the ability to anticipate the occurrence of the disturbances on the sun that have been known for 300 years as sunspots.—HARLAN T. STETSON.

PHOTOPERIODISM IN PLANTS

THE cyclical alternation between night and day is one of the most obvious of natural phenomena. Under natural conditions long periods of daylight automatically correspond to short nights, and vice versa. Over most of the surface of the earth marked variations occur from season to season in the length of the daily photoperiod (number of hours of illumination). Despite the self-evidence of seasonal variations in day-length, it was not until 1920 that experimental evidence was forthcoming which demonstrated that the duration of the daily photoperiod was an environmental factor of paramount importance in influencing the developmental behavior of plants. Although this factor also has recognizable effects upon the vegetative growth of plants (the development of leaves, stems, and roots), its most significant influences are upon the development of flowers and other phases of reproductive growth.

As a result of the earlier investigations of photoperiodism, plants were found to fall into three more or less well-defined categories: (1) "long-day" species, which flower more or less readily in a range of photoperiods longer than a certain critical period, developing only vegetatively in all shorter photoperiods; (2) "short-day" species, which flower more or less readily in a range of photoperiods shorter than a certain critical period, developing only vegetatively at all longer photoperiods; and (3) "indeterminate species," which exhibit no critical photoperiod, developing both vegetatively and reproductively over a wide range of photoperiods. In both the short-day and long-day species the length of the critical photoperiod differs according to species, but it often lies within the range of 12 to 14 hours.

Some common examples of short-day species are asters, dahlias, chrysanthemums, salvia, and cocklebur; of long-day species,

spinach, radish, lettuce, beets, and grains; of indeterminate species, sunflower, tomato, cotton, and buckwheat. Both short-day and long-day varieties may exist even within the same species. Most varieties of soybeans, for example, are long-day plants, but a few varieties, including the well-known Biloxi, are of the short-day type.

In temperate regions the season of blooming of a plant is largely determined by its photoperiodic reactions. Short-day plants, in general, bloom in the early spring or early fall; long-day plants in the late spring or summer. The geographical distribution of many kinds of plants is also in part a function of their characteristic photoperiodic reactions. Obviously a species cannot maintain itself in a climatic zone in which it is impossible for the cycle of its reproductive processes to be completed. In addition to improving our comprehension of the behavior of plants in nature, an understanding of photoperiodism has been used to advantage in controlling the time of blooming of certain plants. Practical use of the knowledge of photoperiodism has found its most widespread application in the greenhouse culture of floricultural crops.

Recent investigations by Russian and American plant physiologists, particularly the latter, have considerably advanced our understanding of the mechanism of photoperiodism. One of the most important discoveries is that the leaves are the loci of the reactions leading to the initiation of flower development. If the leaves of short-day cocklebur or Biloxi soybean plants are exposed to long photoperiods, while the differentiating tissues (meristems) at which axial growth occurs are exposed to short photoperiods, development of flowers does not take place. If, however, the leaves are exposed to short photoperiods while the meristems are exposed to long ones, differentiation of flowers soon begins. Similarly, if only the leaves of long-day dill plants are exposed to photoperiods of suitable length, development of flowers starts very shortly.

The results of certain types of grafting experiments also point to the same conclusion regarding the role of the leaves in the photoperiodic reaction. If a short-day variety of soybean is grown under photoperiods of 17 hours, flowers never develop. If, however, a leaf from a long-day variety is grafted on the short-day plant, formation of flowers soon starts even if exposure of the plant to 17-hour photoperiods is continued.

These experimental results indicate not only that the leaves are the loci of the reactions which induce the blossoming of plants, but also that the influence of processes which occur in the leaves is transmitted to the meristems, causing them to differentiate into floral organs. It appears to be a valid inference, therefore, that a hormone-like substance or substances, synthesized in the leaves only under suitable photoperiodic conditions, is translocated to the meristems, inducing differentiation of floral parts. The name "florigen" has been proposed for this hypothetical flower-inducing hormone. There is evidence that this substance (substances?) can be translocated both in an upward and downward direction in plants, but the distance it can move from the leaves in which it is made seems to differ according to the kind of plant.

If a vegetative short-day plant is transferred from a long day to a short day and exposed to several short-day cycles and then returned to a long day, flowers develop even under long-day conditions. This phenomenon is called "photoperiodic induction." The same phenomenon occurs in long-day species if vegetative plants growing under short-day conditions are transferred to a long day, exposed to a suitable number of long-day cycles, and then returned to short days. The number of suitable cycles required for photoperiodic induction varies according to species.

A fundamental physiological difference between short-day plants and long-day or indeterminate plants is that the former require a cyclic alternation of light and dark periods if flowers are to develop, whereas the latter do not. In other words, short-day plants might just as appropriately be called "long-night" plants. Flowering in the short-day Biloxi soybean, for example, is induced only if the plants are exposed to a suitable number of dark periods, each more than 10 hours long, alternating with light periods of not less than about 2, nor more than 20, hours, and optimally about 11 hours in length.

A reasonable inference from the photoperiodic requirements of short-day plants is that a certain reaction or chain of reactions occurs in the leaves during the dark period and another reaction or chain of reactions during the light period, both of which are essential to floral initiation in such species. Other evidence suggests a further interaction between the products of the light and dark syntheses, the final product perhaps being the postulated "florigen."

The intensity of the light as well as the duration of the period of illumination is also a factor which influences the light reactions necessary for flower development. In the Biloxi soybean, for example, many more flower rudiments (primordia) develop under an illumination of 400 foot-candles than under an illumination of 100 foot-candles.

The dark reactions leading to floral initiation are extremely photosensitive and must proceed without interruption for a period of minimum duration if they are to be effective. For example, in the cocklebur a dark period of sufficient length to be effective in inducing floral initiation becomes completely ineffective if interrupted at its midpoint by as little as one minute of light of even relatively low intensity.

Long-day plants, in contrast with short-day plants, do not require an alternating cycle of light and dark periods. This is shown by the fact that such plants blossom even when exposed to continuous illumination of suitable intensity. However, long-day plants do require a light period of minimum duration out of each 24-hour day in order for floral initiation to occur. For example, in dill, a representative long-day species, the minimum length of the photoperiods required for flower development is between 11 and 14 hours.

The mechanism of the photoperiodic reactions leading to blossoming in indeterminate species appears to be more nearly like that of long-day species than of short-day species. In general, however, indeterminate species can bloom under shorter daily photoperiods than long-day species.

In evaluating the photoperiodic reactions of plants the modifying effect of temperature must also be considered. Apparently temperature exerts a profound effect on at least some of the reactions which control photoperiodic behavior. In general the temperature of the dark period appears to be more critical than the temperature of the light period. Examples are known of species which exhibit the characteristic reactions of short-day plants at one night temperature and the characteristic reactions of long-day plants at a different temperature.—B. S. Meyer.

CAMOUFLAGE PAINT SPRAY

Before the earth-rocking thunders of Pearl Harbor had died away, the entire scientific fraternity of America had become alert to the great demands that would be levied upon its every member. There was so much to know and so little time in which to learn! Every research organization was anxious to convert its equipment and resources to best adaptation for the war effort.

Most of the tree-expert companies in the country turned their attention to camouflage work, which became more and more important as aerial warfare rose to meteoric ascendancy. For many, although not all, types of camouflage involving ground assemblages, it was perfectly obvious that there was no satisfactory substitute for the living tree, shrub, or plant. Large scale plantings and seedings were undertaken to effect a blending of military objects with their surroundings. Grouping of shrubs was practiced to simulate outlines of larger trees, in some cases to give the desired effect quickly. To produce an array of blending colors which would be confusing to the aerial enemy, however, it became necessary to employ paint and pigments on a hitherto unheard-of scale. The application of paint is intended to camouflage objects or areas where trees or shrubs cannot be planted, such as landing strips, roads, and certain types of buildings.

What speedier or more effective method of applying such paints than in the form of a spray, by means of large, high-power spraying machines such as are used to spray shade and forest trees for the control of insects and fungus diseases? This possibility was put to the test just as soon as paint-spraying materials could be obtained. After a few trials, however, it became obvious that the heavier and more costly paints could not be used

in these spraying machines because they clogged the finer parts of the apparatus. On the other hand, the lighter cold-water paints, which were amenable to application by power sprayers, proved unsatisfactory for other reasons, chief of which was the failure of the paint film to build up on the sprayed surface and to resist weathering after it had dried.

It seemed very desirable to develop a paint spray the ingredients of which could be mixed in the tank of the sprayer itself. Such manufacture of paint in the field would obviate mixing, grinding, and packaging of the pigment and vehicle in the factory, thus saving both time and money. To approach this primary objective required the development of an entirely new spray paint combination that could be applied by means of a power sprayer and at the same time would meet specifications for pigment coverage, color, and durability.

The Bartlett Tree Research Laboratories was in a particularly good position to conduct investigations on this problem because one of the company's major research projects had long been the testing of stickers and spreaders for insecticidal sprays. A great deal of time was thus saved by quickly eliminating materials already known through years of testing to be susceptible to the influence of weathering.

After a great number of different types of vehicles and pigments had been tested, it became apparent that best results were being given by those vehicles that would yield a vehicle-pigment combination completely emulsifiable in water. It was further necessary to restrict vehicles to those that would be sufficiently thin for spraying, would cover a surface quickly, and would dry rapidly thereafter.

Experiments finally limited the field to two resin vehicles, one an alkyd resin and one an oleoresin. The latter was adopted because it was easier to handle and dried more quickly after application. The performance of this oleoresin—a linseed oil emulsion—left little to be desired in large-scale application to a great variety of surfaces. The combination was given the name *Bartlett Spracote*. Applications of *Spracote* on macadam roads under conditions of light traffic were still in a satisfactory condition over a year later, while on concrete highways this cold-water-pigment-vehicle combination stood up well for several months under heavy traffic.

One particularly interesting application was made to a planting of thirty-six hundred evergreen trees where branches and needles had died and had become brown, producing a conspicuous contrast with the live green needles. Green-colored *Spracote* applied here caused the needles to look like live green foliage—an effective impression which has persisted now for nearly a year.

Another outstanding development of the Camouflage Spray Research program was the incidental discovery of a synthetic resin that does not injure living plant foliage. There are great possibilities in the adaptation of this material to postwar agricultural spraying for pest control, for it possesses unusual adherent qualities and may also have some insecticidal value.—S. W. BROMLEY, Bartlett Tree Research Laboratories.

BOOK REVIEWS

GARDEN ISLANDS OF THE GREAT EAST

Garden Islands of the Great East. David Fairchild. Illustrated. xiv + 239 pp. $3.75. 1943. Charles Scribner's Sons.

In these days of grim and relentless offensive against the stolen "Empire" of Japan, such names as the Philippines, Celebes, Java, and the Moluccas principally suggest military objectives. Dr Fairchild's *Garden Islands of the Great East* is, therefore, particularly refreshing to the spirit because of the pictures it paints of these charming lands at peace and of their interesting plants and people. We journey with Dr. and Mrs. Fairchild and party as guests of Mrs. Anne Archbold on the motorized junk "Chêng Ho" from the Philippines to Celebes, Java, and a portion of the Moluccas. The latter are a group of small and poorly-explored islands lying between Celebes on the west and New Guinea on the east. For forty years it had been Dr. Fairchild's dream to explore botanically the Moluccas or "Spice Islands." On this expedition, the dream was fulfilled to the extent of brief visits to a few of these islands including Boeroe, Manipa, Amboina, Mandioli, and Halamahera. Soon after the "Chêng Ho" had come to anchor in the harbor of Amboina, the invasion of Holland by the Nazis was announced and the plans for a liesurely cruise among the Moluccas had to be abandoned. Despite this bitter disappointment, it was possible to return to the Philippines via the coast of Halamahera. This permitted the collection of seeds of a number of interesting Moluccan plants as well as a general survey of the coastal vegetation.

As Dr. Fairchild emphasizes, the expedition's scientific results are not to be measured by bundles of dried plants destined for herbaria and technical classification by specialists. On the contrary, he returned "to hundreds of thousands of little seedlings which were already growing up and getting ready to make their debut as Plant Immigrants on the stage of American Horticulture." Among these newcomers are more than ninety varieties of palms, and all students and admirers of this amazing group of plants will hope for their successful development in the Fairchild Tropical Gardens in Florida. The emphasis on the collection of living plant materials, such as seeds, cuttings, and tubers, required special techniques which are described in an interesting way throughout the narrative. Needless to say the availability of air-transportation greatly decreased the loss of all specimens, many of which reached Miami nine to ten days after collection.

In the reviewer's opinion, one of the most significant accounts in the book is the brief and understandably sad description of the famous Botanical Garden at Buitenzorg, Java. This garden is intimately associated with the name of Treub and it was in the company of this illustrious Dutch botanist that Dr. Fairchild in 1894 had his first glimpse of "the world of palms." Now, forty-six years later, the charm and the challenge were still there. One can only wonder whether the Buitenzorg Garden will still exist to educate and inspire other young botanists when the world is once again at peace.

Like Dr. Fairchild's previous books, this volume is sufficiently nontechnical to appeal to a wide audience. The layman will particularly enjoy the numerous excellent and instructive photographs as well as the pleasing style of the author, which is often enlivened by humorous or philosophic comment. To the botanist, the book is an invitation to retrace, at some happier period in the future, the author's journey and to see for himself some of the extraordinary plants which are so vividly described.—Adriance S. Foster.

AMERICA'S GREATEST INVENTORS

America's Greatest Inventors. John C. Patterson. xi + 240 pp. 1943. $2.00. Thomas Y. Crowell Co.

The inventor presents to the mind a bundle of paradoxes. Frequently almost completely ignorant of all but the superficial bases of the science in which he makes his inventions, he nevertheless seems to possess the capability of dissecting from any greater depth of fundamental knowledge as much as

he happens to need for the moment to further his schemes. To the academic mind he is a mystery. At one time he lives in the clouds, which are supposed to be the natural home of all absent-minded professors. At another he becomes the most practical of business men, dabbling in the world of finance in all sorts of conventional and unconventional ways. Perhaps the greatest mystery which he presents to the scholar in this connection lies in the fact that he can find an interest in these matters of promotion, seemingly so foreign to the mind of the student of pure science. Even the urge of reward is not enough to afford an explanation; for, unless that urge is but an accompaniment to a deeper urge inherent fundamentally in the interest born of the task itself, it is doubtful whether any success such as characterizes the greater men of the world would ever be attained.

Not the least of the astonishing situations which characterize most inventors is a keen sensitivity to all matters concerned with patents. To the academic mind, patents are frequently things of another world. They cost no inconsiderable amount to secure, and the academic researcher does not quite know what to do about the matter when the patent is obtained. However, we find the inventor at the earliest age, without any money or resources, somehow or other getting patents on everything he handles. How he does it borders on the miraculous.

For all of the foregoing reasons, it is of particular interest to have this book by John C. Patterson, which collects the pictures of seventeen of America's most noted inventors and places them before us in one setting. We are able to form some judgment of the extent to which they have in common characteristics which may be said to be peculiar to the inventor's psychology. We are able to compare the circumstances which have promoted or retarded their success, and the author has adopted a uniform pattern of exposition which makes such comparison particularly easy. The reader can hardly expect to fathom completely the psychology of the inventor's mind by reading this book, but at least he will gain a composite picture of that individual whose peculiarities invite explanation. The book constitutes very interesting and easy reading. There is no undue elaboration of detail and just enough scientific exposition to make clear the purposes of the inventions to which reference is made.

The persons whose lives are summarized are Eli Whitney, Robert Fulton, Cyrus H. McCormick, Samuel F. B. Morse, Charles Goodyear, Elias Howe, Jr., C. L. Sholes, George Westinghouse, Jr., Alexander Graham Bell, Thomas A. Edison, Nikola Tesla, Charles N. Hall, Ottmar Mergenthaler, Orville and Wilbur Wright, Lee De Forest, Leo H. Baekeland, William M. Burton. Naturally the list of what may be called prominent inventors is not complete, and some may question the selection which has been made to the exclusion of other names which have been associated with great inventive genius. Moreover, the allotment of credit for certain inventions is occasionally a controversial matter. Thus, for example, Edison is claimed as the inventor of the moving picture, whereas, if this reviewer recalls correctly, there has been considerable difference of opinion on this matter, and the claims of others have been strongly urged. However, these are matters of detail, and the author may be congratulated on producing a book which will be read by the man of science and by the layman with equal interest.—W. F. G. SWANN.

THE DELECTABLE MOUNTAINS

The Great Smokies and the Blue Ridge. Edited by Roderick Peattie. Illustrated. x + 372 pp. 1943. $3.75. The Vanguard Press.

WHEN old John Bunyan in his *Pilgrims Progress* described the Delectable Mountains as the next thing to heaven, he could not have foreseen that they would ever become a national park, and surely if he could now observe the throngs of pilgrims who stream into the Great Smokies, he would wonder how some of them managed to get that far on the road to bliss. In the opinion of the reviewer, who has a fair acquaintance with American mountains, the region in and about the Great Smokies National Park is the loveliest of all. The highest mountains east of the Black Hills, their ruggedness is cloaked with forest-cover to their very tops. Since they have never been submerged nor touched by glaciation, they have been a center of distribution

of plants and animals since terrestrial life first began. Within the limited area of the Park there are 130 species of trees (50 per cent more than in all Europe) and 1400 kinds of flowering plants, and the animal life is equally rich and varied. Thus the region is even more interesting to the naturalist and nature lover than it is to the mere sight-seer.

It is therefore particularly satisfying to have this authoritative work on the Great Smokies and the adjacent Blue Ridge. It is the work of seven excellent writers, each a specialist in his own field who has spent many years in his study of this area. The editor is Dr. Roderick Peattie of The Ohio State University, a well-known geographer and author who has been familiar with the region since childhood.

Three chapters, "Indian Days and the Coming of the White Man," "Men, Mountains and Trees," and "Blue Ridge Wild Flowers," are contributed by Donald Culross Peattie, an able scientist and one of our most brilliant writers in the field of natural history. Three chapters, by different authors, are devoted to the human side of the picture. Alberta Pierson Hannum deals very clearly and sympathetically with "The Mountain People" and their nature, way of life, beliefs, and humor. With full knowledge of their subjects, Ralph Erskine writes of "The Mountain Craftsman" and John Jacob Niles discusses "Folk Ballad and Carol" all too briefly, for each of these subjects deserves a volume.

The geologic story, a very complex record of a billion years or so from Pre-Cambrian time to the present, is simplified for the reader by Dr. Henry S. Sharp, who also explains the fascinating peculiarities of the drainage systems. Ralph Erskine gives a good answer to the question "What About the Climate?", noting and explaining the local vagaries and sums it up with the statement that "it is not like anything else in the country."

The Park Naturalist, Arthur Stupka, in his chapter "Through the Year" presents an illuminating description of the Great Smokies, month by month as the seasons change, based on voluminous notes made during his years as resident naturalist. In the final chapter Edward S. Drake, a native of the region who returns as often as he can make an excuse, presents valuable information on the planning of trips. His maps show the roads and main trails, with distances to be covered, and he notes the chief scenic features of each route.

The book is beautifully illustrated with characteristic scenes and contains a good bibliography and an index. It is a very informative and satisfactory account of one of the most interesting and charming sections of our country. The armchair tourist will find much enjoyment, and those who have visited the region will appreciate it as a record of their experience.—R. C. Osburn.

AMERICAN BIRDS

The Illustrated Encyclopedia of American Birds. Leon Augustus Hausman. xix + 541 pp., 700 illus. 1944. $1.98. Halcyon House.

The author of this book is professor of zoology in the New Jersey College for Women, Consulting Ornithologist of the New Jersey State Agricultural Experiment Station, and lecturer in ornithology at Rutgers University. The book is based on some thirty years' experience in field work and in teaching biology and ornithology. In addition to an introduction and a discussion of "how to use the book" (pp. i–xviii), the main part of the volume comprises an alphabetical arrangement of bird subjects under various headings by family, species, and subspecies (pp. 1–468). This is followed by a systematic or classified list of North American birds (pp. 469–503) based upon and reproduced from the well-known A. O. U. *Check List of North American Birds.* Also included is an index of other names of North American birds, (pp. 505–533), an index of scientific names of families (pp. 534–535), a list of Official State Birds of the United States (pp. 536–537), and a bibliography of books useful to laymen in the study of birds (pp. 538–541), including 88 titles of standard books on the subject. The respective entries in the alphabetical sequence include common and scientific names and a brief discussion each of adult male and female; length, distribution, and other like data. Much of the subject matter is supplemented by appropriate drawings. Especial effort has been made to include descriptions of

every bird ever reported from the North American continent, a total of 1422 species and subspecies. Each of the 75 families is described, with data on birds' songs, nests, eggs, and general habits. The Encyclopedia omits discussion of all fossil birds except *Archaeopteryx,* or Lizard Tailed bird, which, being at the present time the oldest known bird, is a matter of interest to all devotees of ornithology. The needs of the nontechnical student have been particularly stressed in the preparation of this work, and this feature alone should add greatly to its usefulness. Then too, those responsible for its publication during these days of wartime stress on economy and conservation of resources are to be commended for the more than reasonable price they have set upon this first edition. It is so low as to place the book within the price range of popular reprints, which should greatly widen and augment its distribution.—J. S. WADE.

TOMORROW WE FLY

Tomorrow We Fly. William B. Stout and Franklin M. Reck. Illustrated. 160 pp. 1943. $2.00. Thomas Y. Crowell.

A BOOK for the layman, or for the scientist who is not a technologist, this little volume gives, readably yet from the expert viewpoint of the designer of the first all-metal (Ford) plane, the tale of the past projected into "the shape of things to come in aviation."

Tomorrow is, of course, the lodestone of science. It is stimulating, therefore, to hear from technologists that we are not yet actually flying. The "wings" we are using are crude—hardly wings at all because they lack flexibility. They cannot "spill" the gusts or rough spots in the air, for example, as a sail on a boat does, and have accordingly to be built to stand terrific strains; all of which makes air-riding rougher than it need be or than it is in the natural flight of birds or insects.

The authors predict, for these reasons, a future for a form of flight which we might call *entom*opterous rather than *ornith*opterous because "birds have individual feather actions that may be hard to duplicate," while "an insect wing . . . is structurally much more simple" and "easier to study." The outlook is even narrowed down to *odon*opterous flight; that is, to the easy way of the dragonfly in outdoing the helicopter in instant control of direction.

If we do take our patterns from nature, however, this reviewer would point out that the hummingbird is almost as expert in control as the dragonfly. The familiar flight of the little ruby-throat is strikingly like that of the hawk moths. Is this because this birdlet falls closest to the range of insects in size? The flight of the largest birds that have retained expertness in the air is characterized by large wings which move slowly. Moreover wings seem to have been disposed by nature bilaterally without exception, as is the case with all locomotor appendages. Such rotary motion as wings have in birds seems to be damped by their eccentric attachment and longitudinal arrangement so that they "flap" the air to the rear after picking up and compressing a charge by the rotation of the front edge of the wing. Is this possibly a commingling of jet and propeller action? The authors hint broadly of fast British planes with auxiliary jet propulsion. They doubtless knew of the propellerless planes now revealed, but obviously felt that wings, affording some recourse if power fails, could not be discarded and would provide the ultimate in maneuverability.

That the limit of usefulness in speed may be reached before the limit in potential performance is suggested, now that "going like sixty" refers, not to miles per hour, but to hours per trip around the "world" of the upper latitudes. On the other hand, lowered costs may present startling developments. What a saving of rubber as air touring takes the place of the auto traffic of today! Some of our plane capacity will carry freight, perhaps at 20¢ per ton-mile (prewar dollars!). Here light weights (new metals, dehydration, etc.) and development of resources (tin, rubber, etc.) by air transport may bring such continental self-sufficiency as to imply less rather than more worldwide trade, despite the ton-mile cheapness of water transport.

"Blind as a bat" has had reference to inability to see with light. But men in aircraft are imitating the bat in using other means of avoiding unwanted contacts in the air.

Supersonic sounds are the bat's way; short-wave electronics are our way of detecting objects that cannot be seen. The shape of things to come in this subatomic field seems nebulous, though atomic fission suggests to these authors a new source of power no longer tied to the solar radiation upon which organic existence has been entirely dependent throughout geologic time. For the present, lest tomorrow we *die*, the human economy will have to confine itself to the conservation of *solar* energy and a correlatively limited population, even in a "new world order."—ALDEN A. POTTER.

CANADIAN-AMERICAN MIGRATIONS

The American-Born in Canada. R. H. Coats and M. C. Maclean. xviii + 176 pp. 1943. $3.75. Yale University Press—Ryerson; *The Canadian-Born in the United States.* Leon E. Truesdell. xvii + 263 pp. 1943. $3.00. The Ryerson Press—Yale.

THESE two volumes belong to a series of studies on the relations of Canada to the United States, sponsored by the Carnegie Endowment for International Peace. The first of this series was Marcus Hansen's *The Mingling of the Canadian and American Peoples* (1940), an historian's account of the changing currents of migration across the Canadian-American border accompanying the westward advance of settlement and varying economic conditions. The two present volumes are in part the statistical sequels of the earlier work, presenting the net effects of this interchange of population as reflected in the Canadian censuses of 1851 to 1931 and in the United States censuses of 1850 to 1930 inclusive. The general reader will probably find the historical account more entertaining, but for the student of migration or of Canadian-American relations, the studies of census materials are invaluable as sources of data and as analyses of the intermixture of the two peoples.

It is known in a general way that the Canadian-American border has been of little hindrance to migration, and that the two countries have interchanged population freely. The net results of this interchange are revealed by the census data. In Canada it is found that the American-born are widely diffused throughout the country and are quite evenly distributed in all major occupations and industries. The Canadians in the United States, especially those of French stock, have shown a greater tendency to concentrate, being most numerous in the cities of the northern and northeastern states, and being employed predominantly in industry. In terms of the numbers involved, the migration has been a much more serious drain on Canada, it being estimated that as of 1931 one out of every eight native Canadians was residing in the United States. On the other hand, the United States apparently has lost less than one-third of one percent of its people to Canada.

The census data of both countries permit a detailed study of the migrants according to geographical distribution, sex, age, marital status, occupation, date of entry, and citizenship. The Canadian material contains additional information on intermarriage and on the religion of the immigrants. The United States census appears somewhat more detailed with regard to family size and economic status, but on the whole, quite comparable accounts are given of both migration groups.

Both analyses are careful and detailed. There is only one point on which no information is given, and that is on the degree of reliability of the data. One might suspect that with such an intimate mingling over so long a period of years, the origin of some of the migrants could easily be overlooked. There is probably no answer to this question of reliability, but any indications would be helpful to the reader.—E. P. HUTCHINSON.

SALAMANDERS OF NORTH AMERICA

Handbook of Salamanders. Sherman C. Bishop. 569 pp. 1943. $5.00. Comstock Publishing Company.

THE salamanders as an order of the Amphibia comprise a group of animals of interest to an increasingly larger number of students. Seldom seen by the layman, salamanders are sought by the naturalist with a sense of "fisherman's luck" that spurs him on. Their very elusiveness, the variety of their form and color, the specific differences in their life histories and behavior, and the sharpness with which their distribution in an area is delineated by ecological niches, lends zest to the study of salamanders by the field zoologist.

Dr. Bishop's recently published *Handbook of Salamanders* is not simply an annotated taxonomic listing of species in this group; it is a highly readable, thorough-going summation of our knowledge of the biology, taxonomy, and occurrence of salamanders in North America, written by a recognized authority who brings together the results of wide field experience and a scholarly digest of the literature.

The salamanders of the United States, Canada, and Lower California are herein described as numbering 126 species and subspecies. This includes all but two of the 102 species recognized in the fourth edition of Stejneger and Barbour's *Checklist of North American Amphibians and Reptiles,* 1939. The twenty-six more recent additions considered valid by the author complete, up to the date of publication, the list of recognized species and subspecies of salamanders of this area.

An over-all concept of salamanders as an order of Amphibia is presented in the introductory chapter in which the author briefly discusses relationships, courtship patterns, care of eggs, neoteny and habitat niches, methods of collecting and preserving specimens, and the use of keys and maps.

The main body of the *Handbook* is concerned with accounts of species, dealt with individually but arranged by families and genera. Descriptions of each natural group of species are preceded by appropriate keys.

Species descriptions list the common name, scientific name, type locality range, and habitat. This is followed in each case by an account of the variations in size that may be encountered in a series of specimens as related both to sex and range of the species in question. Comments on color, markings, breeding time, and behavior have obviously been taken from field notes.

Every species described is illustrated. Adults have been photographed from live specimens, except when indicated, and often from dorsal, lateral, and ventral aspects. Photographs of egg masses and larvae have been included when available.

Distribution maps, made with care and accuracy, and printed sufficiently large to show considerable detail, are an especially valuable contribution of this *Handbook.* Every species is represented in this array of 56 maps. Where subspecies are recognized, their comparative distribution is shown on a single map. Beyond these the author adds no comments as to distribution in relation to ecological factors, although these maps time and again stimulate so many questions in the reader's mind that he wishes Dr. Bishop had introduced some discussion in partial answer. Certain species of salamanders are shown to occur as far northward as the latitude of Hudson Bay and continuously southward to the Rio Grande, while others are confined to areas represented simply by a cluster of dots on the map. The instances of occurrence of salamanders in Alberta, southern Alaska, or northeastern Quebec pose intriguing questions, matched in interest by those pertaining to species whose distribution is remarkably local or discontinuous.

An index of authenticity of the text is the documentation throughout, based on a classified bibliography of 66 pages. Titles grouped as general works, checklists, life histories, and publications by states and provinces of the United States and Canada should prove helpful to the explorer of herpetological literature.

Bishop's *Handbook* is a welcome contribution and an indispensable volume in the library of every serious-minded herpetologist.
—JOHN W. PRICE.

COMMENTS AND CRITICISMS

Teleology Reconsidered

In the May, 1944, issue of THE SCIENTIFIC MONTHLY, Professor Bahm has presented an excellent survey of the teleological argument. The question of purposivity always intrigues the human mind. The argument that "the world has a pattern and therefore must have a purpose" is one which, by reason of its satisfying assurance, makes a general appeal. This immediately raises a question. Why does the human mind seek evidence of a pattern and of a consequent purpose underlying ultimate reality? The answer is to be found in the basic emotional urge which is essential to the human psyche. Man's world is anthropocentric. Man wants to think of himself as the center of the universe. This attempt to explain the world to himself has proven both advantageous and disadvantageous. Negatively, this emotional drive has stood in the way of scientific progress. It explains, for example, the historic objection to the rejection of geocentricity in astronomy. It has served to man's advantage by bringing the realization to his consciousness that the world came into being because of himself. Consequently he utilizes every argument to establish ultimate purposivity. It cannot be denied that the persistent ascription of purpose to the universe gives added meaning to life and impulse to social progress. It is the hope which supplies the goal.

The foregoing argument presumes the acceptance of emotion as a legitimate constituent of human thought. Emotion, if properly directed towards desirable goals, can make a positive contribution to the line of human development. If we presuppose the validity of emotion in the realm of reason, we can find legitimate place for the teleological argument. Accepting this as a point of departure let us probe further into reasons favoring the teleological argument.

With the appearance of the scientific spirit, man begins the observation of nature. He realizes that the discrete manifestations cannot constitute the all of reality. He seeks for an ultimate explanation of the shadowy world of appearance. Gradually the multiverse of appearances give way to a concept of universe. These speculations do not constitute an end in themselves. A question immediately arises. What meaning has the universe—the universe of reality as opposed to the multiverse of appearance—to man? That is, what is the purpose behind the concept of pattern? The only possible answer must be in terms of ethics. Metaphysical speculation must lead to the discovery of ethical sanctions.

Thus we see that ethical conclusions follow as the result of every type of metaphysical inquiry. A non-metaphysical system of inquiry finds the explanation for ethics in mores and folkways. Metaphysical speculation ends in a search after ethical sanctions. For if ultimate reality is purposive and not illusory then ethical sanctions must prove effectually binding. If ultimate purposivity may be read into the universe, ethically binding sanctions must follow as a matter of course.

In this connection it is perhaps possible to cast the teleological argument into another form. Man's pre-eminent capacity lies in the power of perception. Man can think. Man's thought processes are apparently capable of infinite development. Can it not be legitimately argued that the possession of thought on the part of man must be explained as the extension of that thought which is the ultimate reality of the universe? To put it somewhat differently, since thinking man because of his apperceptive-perceptive capacity conceives the presence of purposive designs ranging from immediate experience to the interrelation of the self with the universe, it should follow that the reality beyond all appearance is purposive.

If the ethical sanctions which must follow find acceptance, the human mind will achieve increasingly higher moments in evolutionary development because proper direction will have thus been given to the fundamental emotional urge.—SOLOMON FRANK.

Pleasures and Purposes in Research

In Dr. Alan Gregg's Critique of Medical Research, published in the May, 1944, issue of THE SCIENTIFIC MONTHLY, the devotee of any branch of science may find one of the most encouraging statements of research strategy which has appeared in recent years. By a simple substitution of specific terms its principles became equally applicable in all fields of study, and the manner in which particular purposes are related to general needs sets a good example for all to follow. It was therefore particularly unfortunate, at least in the eyes of this reader, that such an admirable exposition should be marred by a minor statement reminiscent of the claims to royal prerogatives heard in a darker age than ours.

Dr. Gregg speaks very scornfully of those to whom the purely personal enjoyment of research does not provide an axiomatic justification of the demands they must make upon society, or even upon their own abilities, in the pursuit of their desire. As a contrast Dr. Gregg extols the virtue of accepting as sufficient in itself the "almost sensuous pleasure" experienced in the discovery of order and natural law, rejecting, as adulterants needed only by the timid, any corollary feeling of faith and conviction in the ultimate usefulness of all search for truth.

It might be well to remember that even the

Hawaiian missionaries of whom Dr. Gregg is reminded went out to do good to *others* according to their own lights and not merely to obtain the satisfaction of an "almost sensuous pleasure" for themselves only.

This sensuous pleasure in discovery is probably better known and more strongly felt in the subjects of so called "natural history" than in any other discipline, because it is the rule rather than the exception that the student of these subjects is first attracted to them by the sensory enjoyment of nature, rather than by an intellectually developed appreciation of its research problems. But to demand the right to do research at the expense of society in pursuit of a personal pleasure, without even feeling the need for any conviction about its ultimate usefulness, is to claim the privileges of an elite which is not accountable for itself in the manner of ordinary human beings.

To the writer it seems evident that the possession of knowledge is always useful even when the knowledge itself can not be put to practical use. And this conviction seems more than a mere belief developed as a rationalization of a desire. It seems a thesis which could easily be proved if an adequately equipped foundation should care to make a survey of the negative as well as the more conspicuous positive uses of knowledge in human progress.—A. E. PARR.

Adopted

Those of us who use THE SCIENTIFIC MONTHLY as reference material in our classes and who make up bibliographies from time to time would like it if you put a footnote at the bottom of the first page of the second section of a continued article, telling the reader where the first part appeared.—CHARLES J. PIEPER.

To Dr. A. J. Carlson

In your article on "The Older Worker" [THE SCIENTIFIC MONTHLY, July, 1943] you have tackled a problem that goes right to the heart of our civilization. You have marshalled considerable scientific data on the subject. It seems to me that scientific facts ought to go a long way to changing the attitude of the public on this problem. For the sake of the older worker and his contribution to society there should be further scientific study to support your contention. A study of a number of cases of forced retirement might make a contribution in support of a change of policy.

Educational institutions should take the lead in this matter but they evidently have not done as well as industry as shown in the examples of the "Old Man's Division" of the Dodge plant and in the case of the Ford industry. It would seem that in educational institutions where the work is primarily mental rather than physical there should be much concern to conserve the experience and wisdom of the older worker. A blanket provision of retiring all men at the same age completely disregards what is known about individual differences. The blanket retiring age is so unscientific and inhuman that educational institutions should not be a party to such practice.

It seems to me that there can be no valid objection to your proposal of reduced pay for reduced capacity and performance. From the standpoint of justice and decent human consideration for the individual and the welfare of society, our civilization cannot afford to continue to treat the older worker as though he were a commodity without flesh and blood. I know that a blanket retiring age makes it easy for administrators to deal with the older worker. But administration should be regarded as a means to an end and not an end in itself. Personnel departments of educational institutions and of industry and business should be able to work out techniques of dealing with the older workers that would remove the stigma of injustice that now rests upon these institutions.—C. H. FISHER.

Decimation

In "Comments and Criticisms" in the June issue of THE SCIENTIFIC MONTHLY, Peter A. Carmichael is in error when he says, "If Jevons took two seconds per throw . . . then he was at it for the equivalent of some fourteen eight-hour days; . . ."

If 20,480 throws required 2 seconds each, the experiment would have taken somewhat less than 11.38 hours—I presume Mr. Carmichael made a mistake in his decimal point and called this 113.8 hours.

Incidentally, I should like to know what Mr. Carmichael proposes to do about what he has "discovered." I wonder if he would accept as evidence for the defense that the ratio Heads − Tails ÷ Heads + Tails tends to become infinitesimally small as the number of throws increases. We do not "know" that a hyperbole touches its asymptote at infinity, but it is mighty convenient to say so. Or maybe I shouldn't have said that! And how many angels *can* stand on the head of a pin?—ROY K. MARSHALL.

Republished

On page 36 of this issue will be found the poem, "Shall We Speak Out?", which was previously published on page 404 of the May issue in "Comments and Criticisms." We think it merits better treatment than it received in the May issue. The author, Dr. John G. Sinclair, is Professor of Histology and Embryology in the University of Texas School of Medicine at Galveston.—EDS.

THE SCIENTIFIC MONTHLY

AUGUST, 1944

SCIENCE AND THE SUPERNATURAL[1]

By A. J. CARLSON

I INTEND to make this discourse more modest than the title, and I trust you will find it so. Science is one, at least in its essential element, the method of reaching approximate truths. But scientists are many. On the topic before us it is preposterous for any man to speak for science as a whole and, by inference, for all scientists. We have scientists who still pray to the gods, scientists who laugh at the gods, and some who neither pray nor laugh, because they think they understand. I am sure all you expect of me this evening, and certainly all I intend to do, is to discuss the supernatural in the light that years of service in the science of physiology have given me. The topic of this discussion is not of my own selection. The views are my own. But they are neither unique nor original, except in the sense of being derived from cogitation on the common life, cogitations disciplined by years of research. I am not foolish enough to pretend that I am about to present to you anything that is both new and true. There are able tomes on the nature of science; and literature, *ad infinitum,* on the supernatural, especially in religions. There are able works on the conflicts between science and the supernatural. There are attempts at reconciliation of the supernatural with science. We have, in print, confessions of faith in traditional religions by otherwise competent scientists. We have, also in print, rejections of the supernatural by preachers and teachers of religion. I assume you are familiar with some, if not all, of this literature. Everything I am going to say has already been said, perhaps better, by other people. Nevertheless, here is the confession of a physiologist of lack of faith in the supernatural, and his reasons.

SCIENCE

It is scarcely necessary, before this audience, to go into detail as to what we understand by science, although the term is frequently used loosely and with very different connotations. Probably the most common meaning of science is a body of established, verifiable and organized data secured by controlled observation, experience or experiment. Such data frequently lead to an approximate understanding of the causal relations between events, and these relations give us the so-called laws of science. To my way of thinking, the element in science of even greater importance than the verifying of facts, the approximation laws, the prediction of processes is the method by means of which these data and laws are obtained and the attitude of the people whose labor has secured them. In other words, the most important element in science appears to be the scientific method. What is the method of science? In essence it is this—the rejection *in toto* of all non-observational and non-experimental authority in the field of experience. No matter how high in state, church, society or science the individual may be who makes pronouncement on any subject, the scientist always asks for the evidence. When no evidence is produced other than personal dicta, past or present, "revelations" in dreams, or the "voice of God," the scientist

[1] William Vaughan Moody Lecture, University of Chicago. This address was first published in *Science,* 73: 217–225, 1931. It was suggested by a reader of THE SCIENTIFIC MONTHLY that it be reprinted here to remind some and to inform others of the outlook on science and life of a distinguished physiologist, now president of the American Association for the Advancement of Science.

can pay no attention whatsoever, except to ask: How do they get that way? If evidence is produced, he proceeds to examine the evidence. Does the evidence justify the conclusions or statements made? There is nothing recondite or abstruse in the method of science. To be sure, in many fields of scientific research methods of approach, methods of experimentation and data leading to certain or probable conclusions are becoming increasingly so recondite and specific that laymen in general and, in fact, scientists in other fields, are unable to follow, but the principle of the method is simple enough, and that this method of approach will give us the closest approximation to understanding and truth that we are able to reach to-day I think will be agreed to by all informed people.

The principle of the scientific method, in fact, is only a refinement, by analysis and controls, of the universal process of learning by experience. This is usually called common sense. The scientific addition to common sense is merely a more penetrating analysis of the complex factors involved, even in seemingly simple events, and the necessity of numerous repetitions and controls before conclusions are established. Where laymen, as a rule, do not understand or apply the scientific method is in the matter of controls. Thousands of honest errors have been committed and ludicrous conclusions promulgated by failure to understand the necessity of controls. Illustrative instances of this may be cited from the field where I have most experience, namely, physiology and disease. Fortunately, man recovers, as a rule, spontaneously from many diseases, such as colds, pneumonia, typhoid fever, headaches, diarrhea, etc. To be sure, some of these diseases may also lead to death, but if the person having these ailments does not die in the process of the malady, there is more or less complete recovery. Now, if the person not aware of this has the notion handed to him by his father, his priest or his mythology that holy water, holy oil, an amulet, a prayer, the killing of a goat or the laying on of hands will cure these diseases, experience will teach him that after applying any one or all of these measures to the sick persons many of them do get well. Indeed, applying all these to the sick might be a kind of control because a thinking person might be led to wonder which of these measures was the most potent in reestablishing health, and such questioning might lead him to try whether the person might recover without any of them. But usually this is not done. Those who believe that ill health can be cured by prayer will pray. Those who believe that an amulet is a cure will apply the amulet, and those who have faith in holy oil or laying on of hands will try these methods, and most of the people get well. A true statement of the facts is that sick persons so treated do get well after the treatment. The common error made is that the person recovers because of the treatment. The experience is correct. The conclusion is wrong. There is no control. The obvious control, of course, is a sufficient number of people of the same age with the same malady and none of the above measures applied, and the duration of their illness and percentage of recovery contrasted with the treated group. Until consciousness of the necessity of controls in all endeavors to ascertain new truths or in evaluating current theories, dogmas or practices, until this consciousness has become a compelling factor in society, man remains essentially unscientific no matter how much detailed scientific facts he may remember and how much scientific patter he may have absorbed. He is like the rooster who crows every morning before daybreak, notices that a little later the sun rises, and then concludes that it is his crowing which brings the sun above the horizon.

It seems that the supernatural in the sense of religions or a religious attitude toward nature and life is nearly universal among men at some stage of development. Science in the sense of elements of the scientific method, the learning by experience, is even more universal. It antedates man. The amoeba appears to work in part by the principle of trial and error; so do some of the higher animals, including the ape. This type of reaction or behavior in the simpler forms of animal life does not necessarily connote conscious associative memories, but there is no good reason for denying the latter factor in the higher animals. The trial and error method is direct experience. Experience is experimentation in embryo. The

very fact that every known race or tribe of humans has changed (some say progressed or improved) in the practical arts of living, in mores, in social organization and in religion is evidence of some learning by experience, despite all the retarding force of tradition and myths, and despite the absence of conscious control and analysis. Learning by experience, however, can not be dignified as science until a critical analysis of the factors and rigid controls of experience are introduced.

The *attitude* of the scientist is also an important factor in application of scientific method and therefore in the science itself, or at least in the growth of science.

This attitude is, of course, partly characterized by challenge of authority, be it man or God. It is further characterized by a serious attempt on the part of the scientist to control his own emotions and his own wishes in the matter. The scientist is, after all, an ordinary human being and the control of his desires, emotions or wishes in a problem is seldom, if ever, one hundred per cent. The scientist tries to rid himself of all faiths and beliefs. He either knows or he does not know. If he knows there is no room for faith or belief. If he does not know he has no right to faith or belief. He may have grounds for hypotheses, but the moment he begins to have faith in his hypotheses the hypotheses tend to become myths. One of my teachers in zoology used to say to us: "Friends, it is necessary, at present, to entertain theories in zoology, but we must be on our guard against being entertained by these theories." These elements of the scientific attitude I have indicated are scientific ideals which few, if any, scientists are able to attain all the time, particularly when they are dealing with matters of tradition or matters to which they are emotionally conditioned in early youth.

The term science is sometimes limited to the fields of mathematics, astronomy, chemistry, physics, geology, biology, and their practical applications. This may be due partly to the fact that in these fields we have to-day the greatest body of verifiable data and so-called laws of science. However, one of the elements in the scientific attitude is the application of the scientific method to the entire universe, including all human experience and all human relations. The man of science seeks for evidence in the case of all traditional beliefs and practices, and he must abstain from positive views when evidence is lacking in these fields just as he does when evidence is lacking in his own particular field of endeavor. Of course, it is much more difficult to apply the method of science to such fields as religion, social customs, political and economic institutions. Scientific controls are not readily devised or secured, but the application of the method of science in these fields has justified itself by results. It has afforded us a better understanding of the origin of our social heritage, even if it has not to date yielded any considerable body of verified data or laws similar to that of physics, chemistry, geology or biology. To the oft-repeated question—Are psychology, sociology, economics, etc., real sciences?—I would answer: They are, to the extent that the rigid application of the scientific method and scientific attitude is pursued by the people who cultivate these fields. The biologist is confronted in his own field by some of the difficulties that other scientists experience when they enter the fields of sociology, political science, psychology or religion. The past seems to be behind us despite the idea recently advanced that time may actually run backwards. Time may run backwards or in circles in the mind of the philosopher, but it does not seem to run backwards in biology. At any rate the history of the early ancestors of living plants and animals, and possibly the very origin of life itself, is only dimly written in the strata of the earth of bygone geological epochs. We may discover and describe a link here and there, but many of the links are as yet missing. We can not experiment with the past, we can not establish controls. Not only that, but many of the processes in the life of the individual man, animal or plant of to-day appear to be as complex, as difficult to analyze and separate and therefore control as the complex forces in society.

So much for science. If we have rightly understood and correctly outlined the method, attitude and scope of science, we might stop right here, and let you draw your own conclusions as to the supernatural, the

"holy," the "divine." It might be better thus, for those of you who have already done so will be bored by the rest of this discussion; and others might take the conclusions on my mere say so, or reject them because contrary to their faith. In either case further discussion is largely futile.

The Supernatural as a Way to Knowledge

By supernatural we understand information, theories, beliefs and practices claiming origins other than verifiable experience and thinking, or events contrary to known processes in nature, such as the production of wine from water alone; the resurrection from the dead of persons in advanced stages of decomposition; accounts of creation of the world and of man by people who were not present at these events, and not in a position to infer from cosmic data; specific codes of behavior enunciated directly to some man by some anthropomorphic god; arrest of the course of the sun through space so that the Jewish army could see to kill a few more natives; casting devils out of men, and sending demons into hogs; human pregnancies solely through non-material, that is, divine agencies; perpetual recurrence of a species of "immaculate conception" in that a divinity sends embryonic "souls" into every human fetus either at the moment of union of sperm and ova, or later in intrauterine life, etc., *ad infinitum, ad absurdum, ad nauseam.* This supernatural has been presented to man with varying degrees of clarity in a great variety of books and sermons by prophets, priests, and other holy men, in addition to the information in so-called sacred books, such as the Bible, the Koran, the Vedas and the book of Mormons. We all know that there are great variations among modern adherents of the sundry religions both in the amount that they individually accept and in interpretations put on what they do accept of this supernatural. But the supernatural in this sense is found at present in the theories, beliefs and practices of most, if not all, religious groups. We find a sprinkling of it here and there in social habits, customs and ethics. At one time it was prominent in political institutions and theory, but in most parts of the world "rule by divine rights" has been abolished, at least in theory. The gradual elimination of the supernatural and the divine in governments can not be primarily credited to science or scientists. It was forced by the travails of the common life. The supernatural sanction in social customs, habits or ethics frequently touches matters of relatively little importance, such as the interdiction of eating pork for the Jew, and the eating of meats on Friday for the Catholic, the ritual of baptism in the Christian religion, the circumcision in the Jewish religion, shaving or not shaving the face or the head, etc. The dogma that each individual marriage, when solemnized by a priest, is a "sacrament" made in Heaven by Almighty God and holds "till death do them part" has a more practical significance.

I am no authority in this field, but according to the best information now available it would appear that early mores had little or no connection with the supernatural. The grafting of the supernatural on ethics appears to come relatively late in human history. At any rate, so far as the essential mores of practical living is concerned, similar principles have been developed in various social groups independent of, parallel with, or under the influences of a variety of religious beliefs. These, therefore, have the sanctions of social necessity, convenience, or safety quite apart from the supernatural.

The supernatural is particularly abundant in the field of religions. I shall not attempt the impossible, *viz.*, a definition of religion. We have, however, people who entertain religious theories and follow religious rituals. When I speak of the Jewish, the Christian or the Mohammedan religions I refer to the theories, practices and attitudes peculiar to the people in these religious groups. I think we may get somewhere in the discussion if we treat religion in this way rather than by abstract definition. Most religions have in common the view and belief that some time somewhere God or gods, supernatural beings communicated to man information on the origin and nature of the universe, on the origin and nature of man, on the nature and control of the forces of nature about us, on the nature of evil, etc. In most cases these so-called revelations occurred so long ago

that the person or persons receiving them are buried in obscurity and myths. We can not analyze the alleged facts and circumstances. Fortunately, we have in this country two recent divine revelations of this type, namely, Mormonism on the basis of the Book of Mormons, and Christian Science on the basis of the divine teaching of Mary Baker Eddy. These are so recent that the personalities and the circumstances involved are not yet entirely obscured by myths and lore.

What has science to say to all this? The most serious aspect of the supernatural is, not the revelations, *per se*, the miracles, the myths and the guesses, but the injunction that all this must be taken on faith, that inquiry and doubt is tabu—that is, sin. A good deal of "revealed" information about the nature of the world and the nature of man has proved entirely erroneous. So far as the nature of the world and of man is concerned the revelations appear to be nothing but what could have been projected as guesses by any human contemporary of the revelations, on the basis of the knowledge and the ignorance of those times. The "revelations" have been of no aid in the advance of real knowledge of cosmogony, physiology, physics, chemistry or disease. On the contrary, they have, through human stupidity and obscenity, frequently aided in retardation. The revelations to Joseph Smith (the Book of the Mormons), the repeated revelations by Jehovah to Brigham Young, and the rise of Christian Science are recent. The character, education, intelligence and environment of the people concerned are fairly well known. In the light of all the known facts in these instances, is there any intelligent man or woman to-day, not steeped in childhood in the lore of Mormonism or Christian Science, who can have any respect for such revelations as a source of knowledge? When the Mormon leaders received a tip from God that polygamy was ordered by him for his chosen people on earth (by the way, a revelation that is easy to take by the average human male), the United States Government did not hesitate to challenge God, or Brigham Young's sanity and veracity. The Federal Government was powerful and adamant and God yielded through a second revelation to the effect that he had changed his mind and polygamy was no longer according to the plan of God! In some cases the "revelations" are reported as coming through dreams; in other cases through brush fires; by direct writing of the finger of God on stones, or indirectly through oracles, popes, the flight of birds and the liver of slaughtered bulls.

The physiologist can not accept revelations from dreams any more than he can detect wisdom in hallucinations. The brush fire may reveal something of the nature of the world, but it can tell us nothing of the origin of man or the ways of the good life. The supernatural as a way to knowledge is in direct conflict with science.

That many intelligent people of to-day both inside and outside the religious groups reject much of the anthropomorphism of the gods and the more palpably absurd phases of the supernatural as a way to understanding is no news to you. They usually retain a distillate of the supernatural in form of beliefs in a "moral purpose" in the universe. And having injected human ethics into an obviously a-moral universe,[2] they endow man with personal immortality. This refined supernaturalism is still essentially anthropomorphic and homocentric. Even this form of the supernatural has no sanction in science or analyzed human needs, as I understand them.

The Content of the Supernatural Revelations

So far we have considered the supernatural mainly from the aspect of the way of learning, the way of extending knowledge, the way of greater approximation to truth. A word or two on the content of the supernatural seems in place here. Most of the weird stories of creation of the universe, animals, man, of divine or demoniacal control of natural forces, of disease, etc., that have come to us *via* the supernatural route

[2] The concept of moral and immoral behavior has developed in connection with normal human adults or any hypothetical personality, to whom we ascribe consciousness of "right" and "wrong," and a feeling of freedom of choice in behavior. "*A-moral*" signifies the absence of these elements of personality, as in the behavior of young children, animals, the insane, and the physico-chemical forces of the universe.

run contrary to facts now known, or rendered untenable, as possibilities, by known facts. Between the stories in the book of Genesis, as an article of faith, and the planetesimal hypothesis of Chamberlin and Moulton (probably the greatest intellectual achievement so far in the University of Chicago) as a working theory, science *must* choose the latter. Divine benevolence and wrath, devils and demons are not factors in health and disease, according to the data of modern medicine. Science and miracles are incompatible. Much happens in nature and in man for which science has yet no complete analysis of the causal chain. We recognize the unknown but not the unknowable. When we know that we don't know, that is itself an achievement, for then the field is cleared of the confusing and obstructing rubbish of tradition, and we are free to use all our ingenuity and imagination in contriving methods to find out. Miracles of sufficiently recent occurrence so that fair information is available of the alleged facts and circumstances are resolved into misrepresentation or misinterpretation of the facts. In regard to the recurring miracle of changing bread and wine into human flesh and blood by Christian rituals, biological and biochemical tests of the bread and wine after being subjected to such rituals reveal nothing but the original bread and wine. To persons fairly familiar with biology and physiology the theory of animal and human evolution and genetic relations is a closer approximation to what happened in the past than any guess or story in "sacred books" or mythology. I have a fair acquaintance with most of them.

The Theory of dual nature of man (body and "soul") and its equal: The theory of *personal immortality* appears to be partly of mythological and supernatural origin, partly philosophical. The alleged objective evidence of these views is entirely mythological and supernatural, unless we are to dignify as evidence the ancient and modern communications with the dead by clairvoyance, "psychic mediums" and "ectoplasm." When examined, the "ectoplasm" appears to go the way of all errors and frauds. I know these attempts, and I am still skeptical.

Has science anything to say on the theory of personal immortality? The idea of persistence of the individual after physical death came down to us from the ancients in most if not all races. What credibility are we going to give to the idea solely because of its venerable age? So far as I can see, we can give no greater credibility to the ancients' views on immortality than to their views on other things about which they knew nothing. Conscious phenomena and intelligence in man, that is, personality, appear to be just as much an evolution of the material world as is the rest of the body processes. We seem to be forced to this conclusion from the evidence of the intimate dependence of all phases of consciousness, memory, and personality on the quantity and quality of the nervous system, and these, in turn, depend on all the rest of the body mechanisms.

It is perfectly true that we can cut off an arm or leg, remove certain peripheral ganglia and even a certain limited part of the central brain without seriously interfering with consciousness or personality. We can leave the brain structure anatomically intact, and through poisons eliminate consciousness temporarily or alter the individual personality permanently. The data from brain tumors, brain injuries, drugs, such as sedatives, hypnotics and anesthetics, experimental physiology, defective heredity, show that there is a close correspondence or dependence of consciousness, intelligence, memory or individuality on the nervous system.

What is personality? I think biologists would agree, to-day, that one element in personality is heredity, the kind of germplasm with which we are endowed at conception.

In the case of man and other mammals the original germplasm is subjected to months of intrauterine environment. The latter is complex, not simple. Such material factors as the constitution, health and food of the mother appear to have a very real influence on the constitution of the fetus, and after birth such material factors as disease, accidental injuries, food, etc., may further materially modify the final product: man or woman.

The hereditary personality is further modified and built up gradually by experience and memory, so that to-day I am a somewhat different person from what I was twenty years ago. It seems at least highly

probable, on the basis of biology, physiology and medicine, that this experience or the cumulative effect of the environment depends on changes built up mainly in the nervous system. The modifications of the nervous system called memory are less stable than the hereditary elements of the nervous organization. All the present evidence points to the fact that at death the nervous system goes to pieces with the rest of the body. Indeed, the disintegration of the nervous system, and with it the personality, may start before the death of the individual. The tragedies of "second childhood," of the aphasias, of senile dementia are known to all informed people. It doesn't make any difference whether the disintegration is fast or slow. We may preserve for a time some externals by desiccation, embalming or petrification. But fossils and mummies are as dead as the ashes of the funeral pyre. I can not conceive of events and environments in the future that would exactly reproduce my heredity and personal experience. On the basis of the known and the probable, immortality of the person is, at present, untenable. Leaving, for a moment, the realms of knowledge and reason and speaking of personal wishes, of likes and dislikes, the wish for personal immortality may be an extension of the pleasure in living, sometimes called "the will to live." The quantity of these emotions appears to vary in different people. Many seem to find comfort in the theory of "Nirvana," the state of everlasting unconsciousness. "Nirvana" may, without trickery or undue violence to reason, be translated into what modern biology indicates as the end of the individual, but the ways of attaining "Nirvana" appear to me incompatible with the good life here. As for other conditions of existence of the individual after death, other abodes of the "souls," the sundry infernos arouse in me, not fear, but pity and wonder how man can choose to torture his mind with such cruel absurdities; and I have not seen any heaven described where I care to go. My forebears had their Valhalla with its mead, its roast pork, its combats; the American Indian his happy hunting grounds, the followers of Mohammed their heaven of houris; the Christian has his golden city of many apartments, his golden harp and his oriental worship of adulation. But hunting means destroying fellows not so very different from ourselves. A heaven of mead and pork and fights and females forever leaves me cold. Flowers, though they like ourselves last but for the moment, are finer than gold, and justice seems a better goal than worship. When the shadow lengthens I am content to call it a day and leave the work to others. The passing of personal immortality seems to have added interest to my work to-day, greater interest in my students, in my fellow men, in other things that seem worth-while human efforts. For when I die, I will be a long time dead.

I am perfectly well aware that many able and fine people inside and outside this hall will arise with impatience, if not in anger, and say: "Your analysis of the supernatural refers to an extinct species. It does not apply to religions or religious people of to-day. You are belaboring a man of straw." What are the facts? Is supernaturalism a thing of yesterday? Have the peoples of the earth ceased to chant every variant of the tune, "The old time religion is good enough for me"? If the orthodox Jew (and that embraces most of the Jews) has dethroned Jehovah, and rejected the Bible, I have not heard of it. According to the latest news the Pope is still God's viceroy among men and the faithful Roman Catholics still believe that the voice of the Vatican is the voice of God. The acceptance of the whole Bible as divine truth is not a rarity among Protestant Christians. The God of the Jews, the Christians and the Mohammedans in 1930 is not a fossil. Enter almost any religious service and you get an earful of ancient and modern supernaturalism anent the soul, the devil, hell and heaven, sin, redemption, almighty Gods, angels, divine purposes, prayer. Is the supernatural extinct? Take a look on and about this campus, and you will find a very prolific and very recent growth of chapels and churches: edifices, I am delighted to note, only in part dedicated to the rituals of the "God of old." To be sure the supernatural is not in our federal constitution. But it is not absent from state and municipal codes. "Acts of God" are embalmed in legal lore. Physiology and biology can not be taught at

public expense in the states of Tennessee, Arkansas and Mississippi because it conflicts with "revelation." Is supernaturalism dead? What I have said here to-night would subject me to arrest and imprisonment in the state of Massachusetts, and disqualify me as a witness in court in at least six other states in the Union. Yes, my friends, supernaturalism is dead, indeed! Let a Jew, a Roman Catholic, a Mohammedan, or a man of no belief, like myself, run for governor in any state south of the Mason and Dixon line (and possibly in some states nearer home), or for President of the United States and he will discover something! The world has, indeed, moved since the days of Galileo, but in some places it has not moved very far. Why, the handful of liberal and informed people who have worked their way out of a cocoon of supernaturalism does not even make a respectable leaven in the college graduate group!

President Hoover, an engineer, and therefore at home in science, stated in his recent Thanksgiving proclamation: "We have been blessed with distinctive evidence of Divine favor. As a nation, we have suffered far less than other peoples from present world difficulties." This statement appears to imply that a divinity controls economic contingencies and rainfall, and either that we as a nation are morally more worthy than other peoples harder hit by economic and natural events of the past year, or else that this divinity is unfair in decreeing punishments and favors.

According to several Italian churchmen, the recent disastrous earthquakes in Italy were caused, not by unbalanced stresses in the crust of the earth, but by the Christian God, as punishment for the sins of men, women and little children in the devastated areas! Granted, for the sake of the argument, that the bishops are right and modern geology is wrong about earthquakes, we may still ask for evidence that men, women and little children living in earthquake areas are greater sinners than people living elsewhere; and again, if questioning was not tabu, how can a *just* and *loving* god institute such indiscriminate punishment? How can a *just* and *almighty* God permit such catastrophes to occur?

Within the present year five Protestant pastors in our neighboring state, Kentucky, are reported to have published the following statement: "God will and can answer prayer for rain. God has never withheld rain from the earth except in a gracious effort to bring his own people back to the ways of righteousness and holiness." If there is a God both almighty and just, prayer for rain and all kinds of favorable weather anywhere is unassailable. But if rain is sent to earth in proportion to holiness and prayer to Jehovah, the sundry heathens and all worshipers of "false gods" would have a dry time, not to speak of plants and animals who, according to the Bible, have no souls to pray with. Unfortunately for that kind of faith, the rainfall in heathen Philippines (that is, before the introduction of Christianity) was greater than in our Christian state of Tennessee. But this question need not be left in the realm of faith and controversy. It can be settled by controlled observation. What is the ratio of rainfall to Christian, Jewish, Mohammedan or Mormon prayers in various lands? The states of Washington and Oregon (west of the Cascades) have more rain than has the state of California (west of the Sierras). Is this difference due to the wickedness of Hollywood, and the past generation of gold diggers, and the holiness of the lumberjack? The adherents of the supernatural pray and irrigate the arid lands; others merely irrigate. The crops seem to parallel the irrigation rather than the prayers. Were it not for supernatural tabus, many other supernatural claims could be put to the experimental test. It should not be much more difficult to determine the efficacy of prayer against such diseases as syphilis, malaria, diabetes and goiter, than to establish the merits of arsenic, quinine, insulin and iodine. Not very long ago I read a signed public statement by a lady in the state of Kansas to the effect that she had seen a goiter melt away from the neck of another lady during the praying of the Reverend Aimee Semple McPherson directed toward this end. This appears like direct evidence. But metabolism tests, neck measurements and motion pictures of the "melting" process would go further to convince the skeptics. What people under intense emotions and de-

sire to believe think they see has frequently no relation to the light that actually impinges on the retina. Intense faith as well as intense fear seem to predispose to hallucinations in many people.

The moral efficacy of infant and adult baptism could also be tested experimentally, although with less accuracy, until better quantitative measures of human character are worked out. A prominent physiologist told me he had done this experiment in his own family, having two of his children baptized, and keeping the other two children as controls. I will not even mention the results, for we draw no conclusion from so few experiments, but it might be pointed out that identical twins would be the best material for this test. Is supernaturalism dead? Some Protestant clergymen inform us that Jehovah is a prohibitionist, and the people who oppose our present prohibition of alcoholic beverages are fighting God. Some of the Roman Catholics tell us that raising grapes and drinking wine is God's plan for man. Such confusion on the celestial lines of communication ought to provoke thought. It seems to induce nothing but reciprocal anger.

Many people take the position that science is well and good in the "material" world. They would exclude the method and attitude of science from certain fields of human life. A prominent New York rabbi said only a few days ago: "Human feelings and emotions will remain outside the scope of science forever." As if the biological sciences, including medicine, have not already produced a very respectable body of verifiable data on the mechanisms of the emotions. The relation of the brain to the emotions is nearly as clear as the relations of the kidneys to the secretion of urine or the relation of the gullet to swallowing. That complete obstruction of the gullet will prevent swallowing I do not think would be denied even by a rabbi. It is a favorite saying that there is more than science in the universe and in human life. We grant that. At the present the unknown exceeds the known. There is more ignorance than science. But is that a cause for exultation? Instead of wasting time and energy in the futile effort of building fences around science, and in a meticulous labeling of the "unknowable," we had better join hands in tackling the unknown, not with worship, prayer or propitiation, but with the tool of science. Here is useful and joyful work for everybody.

The Ethics of the Supernatural

May I make a few concluding remarks on the ethics of the supernatural, speaking not as a scientist but as a common man? The ethics of science is simple: absolute honesty in recording and presenting data, and curbing wishes, personal prejudices and emotions by reason in interpreting the data.

There appears to be a great variety of ethics in the supernatural. Looking upon the supernatural simply as man's early stumbling attempts at learning, at adjustment, as flounderings toward greater happiness, as quests for explanations of the unknown, this variety is both inevitable and understandable. From this point of view, the modern man of science has no essential quarrels with Jesus, Confucius, Zoroaster, or Buddha. They did the best they could, considering the ignorance of their times. We can do no more. But now and then individual champions of the supernatural have been either unusually stupid or inordinately selfish and cruel. The judgment of posterity will be severe on the men who coerced Galileo and their brethren of to-day who know or might know, yet rivet the shackles of supernaturalism on the human mind. For they sin against man. It is significant that neither Jesus nor his apostles appear to have claimed any supernatural authority or absolute wisdom for their sayings or writings. The ignoble doctrine of divine revelation of absolute truth for all times appears to be a later invention. But in Mormonism and Mohammedanism it is present with the founders. I said: ignoble doctrine. Intellectual tyranny is to me as immoral as physical tyranny. Stifling freedom of inquiry and of thinking by religious tabus or legal dicta appears to me highly immoral.

The view or belief that some one man or group of men (such as Brahmins, popes, priests, etc.), above all other humans, is specially endowed or enlightened to perpetuate and advance truth, and mediate between gods and man favors tyranny. It

seems inimical to knowledge and human dignity, hence immoral.

The supernatural theories of "sin," personified evil, redemption, eternal damnation, etc., when actually believed, have created and are creating much disturbance in man's emotional life, in the way of fear, worry, melancholy, if not outright insanity. The theory or doctrine of the vicarious atonement in the Christian religion is not only a projection of views and practices of barbarism into modern life, but it connotes a principal of punishment and propitiation at variance with modern sense of justice. It goes without saying that many Christian people are not aware of this.

If we take a look at the gods, they can be understood and condoned as inventions of man, at varying stages of social development. The fossilization of nearly all so-called sacred books by edicts and tradition has brought about the anomalous condition that the best people in many religions to-day are ethically superior to their gods. In the recent invasion of Palestine the modern Israelites have shown themselves in treatment of the Arabs, by and large, superior to Jehovah of the Bible.

If man as well as his social environment remained stationary, static mores might serve very well. But social, economic and political life appears to be more fluid than man. Hence the necessity of continuous amendment of the mores. For example, the travail of modern life is forcing the practice of birth control into the open for a more rational and humane settlement, despite the thunders from Mount Sinai and the echoes thereof from the Vatican Hill. If a physiologist, in 1930, may venture to reinterpret the aphorism of Paul, anent faith, hope and charity, it would read something like this: Faith is of the past, hope must be chastened by experience, charity in modern garb, is misdirected benevolence. But there remains the endeavor towards understanding, the hunger for beauty, the urge for justice—these three, and the greatest of the three is justice.

Science nurtures inquiry, the supernatural stifles it. The two are in their very essence incompatible, but they can apparently coexist in some scientists of the first rank. Man is, indeed, a perplexing animal. He is rarely consistently consistent or consistently inconsistent. The crook is not always crooked, the murderer not always cruel, the thief not always greedy. An honorable person may lie and a liar sometimes tells the truth. A shrewd business man may consult a soothsayer and be afraid of a black cat. Most men in early childhood are emotionally conditioned to the supernatural, just as they become emotionally conditioned to other elements of childhood environment: parents, places, playmates, nursery rhymes, the old swimming hole, and what not. Retaining and recalling these emotions please us. Adults may be conditioned, but usually with less emotional content than the child. We can be conditioned to science or justice just as to the supernatural, but the latter usually gets there first. The conditioned emotions usually outlive one's intellectual metamorphosis. Their disappearance seems to be a slow atrophy of disuse. Many factors appear to enter into the persistence of early conditioning to the supernatural, such as group loyalty, the desire to conform to social usage, the disinclination to disturb or distress parents and other intimate friends; social, political and financial ambitions, etc. Men also appear to differ in the emotional satisfaction obtained from the mystic. Additional factors, such as individual emotional capacity, may be operative in making some scientists think and work, while others think and work and pray. I admit it may be easier for men in the physical sciences than for biologists to cling to the supernatural, for much of the grotesque in the supernatural concerns man and other living things rather than inanimate nature. But even so, it is a fact that Rev. Stephen Hale laid the foundation for the science of hemodynamics, and Friar Mendel discovered fundamental principles in heredity. So far as I know, the Reverend Hale and Friar Mendel were sincere adherents of their respective religious cults. Our social heritage, good, bad and indifferent, clings to us like the hand and the appendix of organic inheritance. Hence, like the proverbial Englishman, we "muddle" but, now and then, we "muddle through." Fear and faith have ruled much of man's past, but the millennium is still far, far away. Now let us

try what may be accomplished by undertaking. Give science a chance.

I seem to sense a silent sigh from you, saying: "Thank God, he is through." I am—nearly. Knowing next to nothing about public speaking I consulted an experienced colleague, before preparing this talk. He referred me to a well-known canon, which reads: First, you tell your audience what you intend to tell, then you proceed to tell it, and lastly you tell what you have just told. You may have observed that I have followed this advice. I have now reached the lastly. Lest I be accused of hiding my real views in a plethora of verbiage, I will attempt to sum up, in threescore words, what I tried to say in seven thousand: As I see it, the supernatural has no support in science, it is incompatible with science, it is frequently an active foe of science. It is unnecessary for the good life. And yet, the supernatural, in varying dilutions, is likely to persist in society for a very long time. The unconditioning and reconditioning of mankind in fundamentals has been a slow process in the past. It may go a little faster in the future. It is a matter of forgetting the hypothetical universe created out of ignorance and motivated by our undisciplined emotions; and a reconditioning to the actual universe, as gradually understood through controlled experience and experiment.

SCIENCE AND HUMANISM

The current discussion of values in college education seems determined to fix in the public mind a distinction between humanistic studies on the one hand and scientific studies on the other. It is a distinction that, in fact, does not exist. If the greatest humanists of past centuries were to be resurrected and introduced to modern knowledge, I think that they would be much more interested in science than in critiques on creative work already done in the humanities. They would be disappointed by the wide turn in college from creative work to talk about it; and they would doubt the purposes that are to be served in any civilization by such "exercises." They would deplore the glibness and cocksureness that generally mark men who graduate under glib and cocksure teachers absorbed in the study of dialectics to the neglect of judgment. They would be more inclined to enquire about the steps by which men reached the point of discovery and relationships of forces until recently unknown, and of textual interpretations unguessed by their precursors. They would be interested in the mental climates of successive decades that preceded given discoveries. They would want to know about the critical effects of a given enquiry upon further enquiry and the mental saltations and sequences that enabled a man to reach the goal of an important discovery.

I feel sure that they would also ask about the social consequences. They would probably be amazed at the extent to which these consequences are neglected by schoolmen, industrialists, and statesmen alike, until they are fastened upon the people. They might end by regretting, as we do, that social understanding and control have lagged behind the physical and biological sciences. But I cannot imagine them regretting that discoveries had been made. On the contrary, I think of them as wishing to jump in and help further discovery along and greatly excited by the opportunity.

Put in another way, these humanists of an earlier period would say that the thing of chief interest to them is discovery, and that new knowledge bearing on life and civilization is just as important in our already complex times as in past times. I cannot believe that we have made a sound educational plan, or improved our more or less established college curricula, until we have rubbed out the line that commentators keep drawing between the sciences and the humanities. It is the constant interplay between the new and the old, whatever the kind of knowledge it may be, between the accepted interpretation of past experience and the challenge to interpretation of present discovery, that gives us a balanced judgment and a wider and sounder application of knowledge to life.

It is for this reason in part that the history of science becomes of increasing importance. It is also for this reason that the training of men in the sciences in our graduate schools should not be merely professional or technical. It is neither safe nor true to draw generalizations about the deficiency of scientists or of humanists as groups: one can find bad examples in either group. What is important is that we should reduce the number of such bad examples. We should make a Ph.D. mean something more than proficiency in a small sector of a great subject. A man should be capable of thinking about the meanings and the applications of his science, and not merely about a job in teaching "courses" or advancement in salary in an industry by knowing enough to hold his job. He should be expected to see the importance of the great thresholds of scientific discovery and of humanistic interpretation and he should be eager to cross them and feel the excitement of the search.—*From the Annual Report (for 1943) to the Trustees of The Johns Hopkins University by President Isaiah Bowman, predecessor of Dr. Carlson as President of the A.A.A.S.*

PRECIPITATION AND STREAM FLOW

By CLARENCE S. JARVIS

Long before the introduction of systematic snow surveys, irrigation farmers had undertaken the appraisal of their prospects for water supply by noting the snow accumulations on mountain passes and on the slopes visible from the valleys. Actual rainfall records, including all forms of precipitation, together with well-organized snow surveys among the headwaters areas, now furnish the essential information for making the planted acreage proportional to the prospective water supply.

In some instances glacier-fed rivers have shown apparent disregard for the current season's snowfall. For example, in a year of drought the more abundant sunshine should insure greater melting of the ice surface, thus compensating in some degree for the deficient snow cover elsewhere. The almost universal trend among glaciers observed in recent years seems to be recession of several feet per decade. This may indicate either a decrease of precipitation or an increase of sunshine, or possibly both of these tendencies as compared with long-period averages heretofore.

In general, stream flow represents some fraction of the precipitation of the current year or season, together with some of the storage accumulated in previous months or even years. Some hydrologists prefer to regard the runoff as a residue, after the various losses have been subtracted from precipitation in all of its various forms. Assuming that the precipitation is known, and also the temperature, humidity, wind movement, and hours of sunshine, a fairly satisfactory estimate may be ventured regarding evaporation from free water surfaces, from the soil, from foliage and other surfaces of vegetation by transpiration, and its counterpart from ice or snow surfaces by which the moisture is transferred to the atmosphere through sublimation. After a few hours of drying winds, a snow or ice surface may become honeycombed, as a preliminary to its complete absorption into the atmosphere.

Mississippi valley rainfall and runoff. It has been officially determined by the United States Weather Bureau that the average annual precipitation over the Mississippi River drainage basin is 30.1 inches, and it has been disclosed by the publications of other Federal agencies that the average discharge, or surface runoff, amounts to approximately 6.9 inches over the entire basin, or 23 per cent of the rainfall in all its forms. The remaining 77 per cent evidently returns to the ocean or escapes from the Mississippi Valley mainly as atmospheric moisture, and in minor amounts as seeps and springs.

Evaluation of this fundamental datum of annual runoff depth for the average year is but a beginning in the study of stream discharge. The wide variations in stage and flow from extreme drought conditions to high flood, or from month to month and from day to day, all are important and predictable in varying degrees, as has been demonstrated by many years of notable flood forecasting and associated hydrologic service. Expressed in terms of the past 70-year mean discharge, the maximum and minimum values for the Mississippi River at or near its mouths would be 2,440,000 and 102,000 cubic feet per second (c.f.s.), as compared with a mean of 635,000 c.f.s. It should be recalled that more than three times the mean discharge is escaping in the meanwhile to the ocean or to adjoining drainage basins by atmospheric movement following evaporation or through underground channels.

Probably the increased opportunity for evaporation afforded by irrigation and other water utilization projects, including their great storage reservoirs and canal systems, may represent about 4 per cent of the mean discharge at the Mississippi River mouths, or nearly 1 per cent of the total precipitation. This subtraction from river discharge only partially compensates for the increased runoff due to the drainage of natural lakes and swamps, the clearing of forested areas, and the cultivation of meadow

or range lands, with attendant soil erosion, and gullying; all of which aggravate the flood menace.

Variability of discharge. In view of the dearth of actual records on many of the great river systems, and also because of the difficulties encountered in obtaining such fragmentary data as have been assembled in many foreign languages, the discharge habits of many obscure river systems have remained enshrouded in mystery. Recent accessions of actual discharge records, however, have supplied the required basic information on which to compute, estimate, or interpolate preliminary values of some of the hitherto missing quantities. One of the disturbing influences is the widely varying duration of records, with different terminal dates. Consequently the means thus provided may reflect periods in which either subnormal or excessive rainfall occurred.

Table 1 shows the variability of discharge

TABLE 1
CHARACTERISTICS OF SELECTED RIVERS

River	Mean annual—		Runoff factor	Variability of discharge
	Precipitation (P)	Runoff (R)		
	Inches	*Inches*	*R/P*	*Max./Min.*
Amazon	64	19	30	9
Colorado	13.0	1.3	10	438
Columbia	29.0	14.4	50	20
Mo.-Miss.	30.1	6.9	23	24
Nile	32	1.2	3.7	160
Ohio	44.2	18.3	41	75
St. Lawrence	35.0	12.5	36	6
Tennessee	50.0	22.9	46	97
Volga	17	3.8	22	60
Yukon	14.0	9.0	64	25

for selected river systems; that is, the maximum divided by the minimum discharge. Obviously, this method of comparison would not serve for rivers that go dry, as the quotient of any integer divided by zero would be infinitely large. Owing to storage of its water in the Great Lakes, the St. Lawrence shows a variation of only 6 between maximum and minimum discharge in contrast with slightly more than 1,000, 2,000, and 3,000, respectively, for the Potomac, Humboldt, and Brazos Rivers.

If undisturbed by man, the flow from a typical mountain brook at the edge of a desert region may extend a considerable distance into the arid basin in the early morning and to lesser distances as the evaporation increases with the heat of the day. This illustrates on a small scale some of the changes to which large river systems are subject along their long, tortuous courses. Thus the drainage area of the Nile has a mean annual rainfall of about 32 inches, but the river actually delivers only 1.2 inches to the lower delta region, or barely 4 per cent of the rainfall. However, if the measurements were confined to the headwaters astride the equator, the rainfall would be found to exceed 60 inches, and the runoff would probably reach at least 30 inches because the water rushes down steep mountain slopes of Kilamanjaro and other mountain peaks rising to elevations of three miles or more above sea level. A higher runoff would be prevented by transpiration from the dense jungle growth and by evaporation from storage water in Lakes Victoria and Albert, as well as from extensive marshes along the river channel. That modest 4 per cent of the annual rainfall, which habitually caused the Nile to overflow and irrigate the rich valley and delta lands, practically always insured abundant harvests, so that it could be said generally throughout the centuries, "There is corn in Egypt."

As for the other 30.7 inches of moisture supplied by rainfall over the broad expanse of the Nile River basin—only about 10 per cent less than the Mississippi Basin in area—who can say that it represents absolute loss? How many of the oases are supplied by the underflow from valley fill or from stratified rock formations? How many of the freshening showers of Eastern Africa, Arabia, and Palestine originated in Nile Valley evaporation? And how about the bountiful forest and agricultural products of the Upper Nile basin?

Comparison of outstanding river systems. In the higher latitudes, where annual precipitation is mainly in the form of snow and is usually limited to equivalent rainfall of 16 inches or less, except for mountainous country, the perpetually frozen subsoil pre-

cludes loss into deep formations, and the reduced evaporation limits losses into the atmosphere, thus increasing the runoff factor. For such conditions, the runoff will generally represent 30 to 60 per cent of the precipitation, depending on local factors such as summer temperatures, humidity, wind movement, and exposed free water surface. In contrast, from many of the river basins in equatorial regions less than 30 per cent of the rainfall runs off, because the dense jungle growth returns as much moisture to the atmosphere as would a free water surface, or occasionally more. Who can deny the suggestion that the successive afternoon torrential downpours of the tropics merely precipitate the transpiration and evaporation of the previous day in neighboring jungles?

Determination of drainage areas naturally requires the use and interpretation of the best available maps. The main channel length necessarily includes the midstream distances around bends of both the main river channel and also the principal tributary among the headwaters, even though they may have different names. The lengths compared are those of the channels along the main stems of the river systems, from source to mouth. The longest river channel is the Missouri-Mississippi, with the Amazon and Nile coming next in order, each 4,000 miles or more. The mouth of rivers flowing into the ocean is to be regarded as a point near, but not in, an estuary.

One of the familiar items of elementary school geography has to do with the Orinoco headwaters, one portion turning southward into the Rio Negro, a tributary of the Amazon, thus making an inland waterway connecting the two river systems, particularly during the season of high water. Similarly, but in somewhat less degree, light draft boats may pass from the headwaters of the Guapore branch of the Amazon's great Madeira River to the Paraguay River system.

The La Plata River is essentially an estuary, disturbed by tidal movements throughout its 200-mile length. The discharge of the La Plata is taken as the summation of discharges from its tributaries, such as the Uruguay and the Parana, including the Paraguay. Naturally, the length of channel includes that of the Parana to its headwaters on the slopes of a mountain almost within view of the heights overlooking Rio de Janeiro. The Iguassu or Curitaba River, a tributary of the Parana, plunges over falls much higher (210 feet) than those of Niagara, with considerably greater flood volume, but probably lower mean flow.

Value of fragmentary data. Where the basic data are scanty, incomplete, or of uncertain quality, as for the inland basin draining into the saline Sea of Aral, a valuable clue or check is afforded by equating the evaporation from the expanse of free water surface against the runoff from the mountainous rim and increasingly arid plains approaching the saline sink. If the total drainage area is 40 times the area of the inland sea, and if the average annual evaporation for the globe is applicable, say about 40 inches, then the runoff from the total drainage area would obviously be one inch in depth for the same period. But for the Sea of Aral, about 50 degrees North Latitude, and with climatic characteristics, especially temperature, somewhere between those of Tashkend and Turgai, U.S.S.R., in what was formerly Turkestan, it is probable that somewhat less than the average evaporation rates for the globe would prevail there, and that the runoff would consequently be somewhat less than one inch. Similarly, evaporation from the Dead Sea of Palestine, with its surface nearly a quarter of a mile below sea-level and with subtropical temperature and aridity generally prevailing, must be of the order of 50 inches per year; and this agrees with the volume of runoff, 3.7 inches, as determined for this basin, of which the Jordan River is the chief contributor.

Uncertainty attaches to the estimates of mean annual precipitation over large drainage basins, even where numerous station records are available, inasmuch as the remote or thinly settled areas, such as jungles and high mountain slopes, possibly receiving the heaviest rainfall, may have inadequate representation among the basic records. Furthermore, the occasional gagings of remote rivers and tributaries may depart widely from the long-period means.

Hardly a season or a year passes without the establishment of new records in high or

low rainfall and associated river discharge, in various parts of every continent. It is well known that subnormal rainfall in two or more successive years aggravates the shortage of runoff, because the underground reservoir has been depleted and not refilled to its customary level. Conversely, successive years of excessive rainfall not only refill the usual underground storage space, but also develop new ones, so that the high or low river discharge of a series of abnormal years must be explained partly with reference to the year or two preceding. An outstanding example is the Mississippi River flood of April 1927, which was actually forming and giving cause for concern, if not alarm, months before its culmination. Fortunately, the Federal agencies as well as the local municipalities whose duties include provision against catastrophes associated with excessive river flow or with severe shortage have taken to heart the lessons of the past and have endeavored to make ample provision against recurrence of such happenings without forewarnings to all concerned. In such emergencies they have to integrate the fragmentary data as they become available and then draw conclusions based largely on previous experience under conditions approaching those under observation. It is remarkable how their forecasts are usually borne out, several hours or even days later.

Mean annual precipitation and evaporation over the globe. A coincidence worth noting is that both the evaporation from a free water surface and the precipitation for the average year at Washington, D. C., are about 40 inches, or nearly the mean for the entire globe. In high latitudes as well as at high altitudes, the total annual evaporation in all its forms may be as low as 6 inches, largely due to the low temperature and to the correspondingly restricted moisture capacity of the atmosphere. In desert regions near the tropics, the annual evaporation may exceed 80 inches from a free water surface, particularly for shallow depths that may be warmed each day of bright sunshine.

Under desert conditions the free water surface of river systems is either reduced in area or else subjected to heavy toll. From each occasional shower the sandy soil absorbs a generous portion for storage at depth while the surface dries and provides the needed insulation. Only by reason of the small area of free water surface relative to the total drainage area, can a river like the Nile, the Niger, the Colorado, or the Rio Grande deliver any considerable volume after meandering nearly 1,000 miles through country of such pronounced aridity that water lost by evaporation exceeds by four or more times the actual rainfall of the lower valley.

Storage losses. The penalty paid for regulation of the Rio Grande by storage in Elephant Butte Reservoir amounts to some 20 per cent of the mean flow, and it is well worth while at that price. Similarly, Nile River regulation through storage at Aswan probably exacts a toll of about 6 per cent. However, the total storage from the Aswan Reservoir to the headwaters in reedy swamps, natural lakes, or recently constructed reservoirs permits evaporation of possibly double or treble the volume that now reaches Aswan for use in the delta regions. No one can reasonably deny that the 4 per cent of the rainfall regulated at Aswan is more valuable than would be 16 per cent of unregulated, highly variable discharge that would endanger the economy of the entire alluvial valley, along with life as well.

The great depth of Lake Mead above Boulder Dam on the Colorado River is one of the factors accountable for keeping the storage losses in that reservoir at somewhat less than 10 per cent of the inflow. If the regulation had cost 40 per cent instead, it would still have been worth while, for undoubtedly some of it would return as rainfall to the same basin.

After observing the general inundation along the lower Potomac River and over Potomac Park, including some residential and business districts in March 1936, who would have imagined that the flow would ever diminish to such a low stage as to threaten shortage in the municipal water supply for the District of Columbia and adjoining metropolitan areas? It is generally known and accepted that adequate storage for regulation of the Potomac River can correct both situations.

An important factor in storage and chan-

nel loss is infiltration of water into the sedimentary deposits of bed and banks, thence to emerge at lower elevations in either the same valley or neighboring basins and to supply seeps, springs, water tables within reach of roots, or even outcropping at some oasis or depression. Such underground storage and distribution systems, under pressure in artesian areas and largely exempt from the usual losses to which surface streams and storage are subjected, have thus far been traced, utilized, and appreciated only in part; but what rich dividends the geologists have brought forth from this field!

Rivers of Greenland. The Greenland Icecap may be regarded as the principal river of that island-continent, with mouths or outlets leading down to the coast in all directions. Under the pent-up pressure developed by hundreds or perhaps thousands of feet of ice and snow column, the cap yields to plastic flow; and when the overhang is sufficient, end-slices of the mammoth layercake are sheared off by their own weight into the sea. Occasionally the intact carcass of some form of life is disclosed as the icebergs melt; but the chill induced in the neighborhood of these floating masses, and the associated fogs that add further hazards to navigation and observation, have kept such discoveries as very rare happenings. Therefore many a page of natural history has been turned but to melt unseen and likely never to be read. If the runoff from Greenland only keeps pace with the mean annual precipitation, it is probably nearly 12 inches per year, while evaporation and sublimation together would account for nearly 6 inches; but no one has determined whether the ice-accumulation reserves of past ages are being either augmented or overdrawn during the average year.

Wherever the mountain elevations and precipitation are sufficient, icecaps in miniature are to be found, even near the equator, from the southern island of New Zealand to the principal mountain ranges of the Americas, and from the Himalayas to the Alps, providing very important and valuable adjuncts to the regulatory storage, and capable of functioning apparently as well in years of drought as in seasons of plenty, with volume of yield and time of delivery fairly predictable months in advance, and therefore encouraging comprehensive planning for complete utilization. And as to the river systems with spring sources on the plains and lowlands, how many of them depend upon high mountain basins, connected by underground channels, even though they be either the joints and planes of stratification or porous sedimentary rocks, yielding to enormous water pressures from highlands?

TREES OF SOUTH FLORIDA*

II. FIVE NATIVE CABINET WOODS

By JOHN C. GIFFORD

WOODS that are regarded as suitable for the construction of fine household furniture are called cabinet woods. Such woods are generally characterized by beauty of finished grain, by strength and hardness, and by adaptability to carving. These are the characteristics of heartwood from the five species of trees to be described in this article: lysiloma, mahogany, fishpoison-tree, false-mastic, and lignumvitae

In South Florida these trees are found in wooded areas that Floridians call hammocks, a name, probably of Indian origin, that should not be confused with hummock; although sometimes a hammock island in a prairie looks like a hummock or small hill. The word hammock refers to a mixed growth of hardwood trees occurring in tropical countries wherever the annual rainfall is about fifty inches. Sometimes palms are included, as in Royal Palm Park near Redlands, and further north there are many cabbage-palm areas, which are also called hammocks.

I do not call attention to these five cabinet woods for the purpose of establishing woodworking industries. An outside market for the wood is not needed since all that we have has been, and can be, used locally. The sole purpose of this paper is to direct attention to the fact that these woods are native, that they can be grown easily in South Florida, and that the trees now remaining should be protected to prevent their extermination.

LYSILOMA

Lysiloma, like casuarina, is a generic name which, at least among foresters, has become the common name of *Lysiloma bahamensis* Benth. Foresters object to the more prevalent name "wild-tamarind" because lysiloma is not a tamarind. But by whatever name it is called, it yields a valuable cabinet wood, combining the virtues of black walnut and mahogany. The wood of lysiloma is heavy, hard, tough, close-grained, rich dark brown tinged with red, and with a white sapwood. It is occasionally used and valued for shipbuilding, and a wood that is used for shipbuilding must be good.

Like lebbek, described in Part I, lysiloma is a leguminous tree. Its foliage is light and fernlike and is often a beautiful reddish color like that of the mango and other tropical leafage when young and tender. Lysiloma bears white flowers, about one-third of an inch long, in dense heads. The fruit is a thin and papery pod containing many dark brown "beans" about half an inch in length.

FEATHERY LEAVES OF LYSILOMA

Although limited in its distribution, lysiloma is one of the hardiest trees in South Florida. It has withstood fire and hurricane better than many other species. A heavy seeder even when young, it would, if encouraged, soon cover our rocky inland keys and our shore keys with a rich mantle of green.

Lysiloma not only provides a wood of beauty and durability, but is useful, like lebbek, for increasing soil fertility through

* Continued from p. 28 of the preceding issue.

the fixation of atmospheric nitrogen by the bacteria on its roots. Mahogany would grow in association with lysiloma and would be benefited by it. Lysiloma could also supply shade needed in tropical agriculture. In spite of its many virtues, lysiloma has attracted little attention and all the economic literature relating to it would hardly fill a printed book page.

There were once some very large lysiloma trees in a hammock in Miami—now Simpson Park—and they are still quite common in the hammocks of the Redland District and on the keys. Fortunate as we are in having this rare, majestic, and useful tree in our hammocks, it seems strange that we have never appreciated it; on the contrary, we have cut and burned it as if it were a useless weed. Many logs of this precious wood have rotted in the forest and some big trees, killed by fire or girdled to make way for the growing of truck crops, are still standing although long dead and bare. On the keys, where hardwood forests were destroyed long ago to clear land for growing tomatoes (they could have been grown on prairie land instead), young lysilomas are spreading by the thousands to repair the damage.

Almost every tropical country has a leguminous tree that it fosters and cherishes. The lysiloma is still waiting to be discovered in South Florida.

Mahogany

Floridian mahogany is now in such great demand for furniture and boat construction that every acre of wild land is being searched for trees. Airplane reconnaissance is now being used to spot the big trees in the dense hammock islands in the mangrove swamps.

Unknown to the public is a spot in South Florida where a group of virgin mahoganies is surrounded by swamp. These trees are three or more feet in diameter, breast high

A GROUP OF LYSILOMA TREES SHOWING THE WHITE BLOOM

A BRANCH OF MAHOGANY SHOWING LEAVES, FRUIT, AND SEEDS
THE SEEDS (RIGHT) ARE WINGED LIKE THOSE OF THE MAPLE, ROTATING AND DISPERSING AS THEY FALL.

They are broad-spreading with humus a foot or more in depth beneath. Living in the surface duff are rats, which no doubt feed on the seeds of the mahogany and false-mastic trees, and also on tree snails. Rattlesnakes in turn feed upon the rats. Lysilomas and fishpoison-trees are also present. Perhaps there are other such spots that might be preserved to show this and coming generations what once was widespread. We fail to realize that the landscape is constantly changing through man's interference, and what some of us saw in the Florida of old will never be seen again.

Mahogany is so well and favorably known that many other woods have taken its name in vain. It has been hard to convince people that the genuine, old-time mahogany is native to Florida; that it was, in fact, common at one time here. Botanists have known this for many years. In the winter of 1942–43 unusual cold weather killed unprotected vegetables, yet the mahogany was not injured, indicating that it might be grown even farther north than its present range.

The mahogany of Florida (*Swietenia mahagoni* Jacq.) is heavier than the mahogany of Mexico and Central America (*Swietenia macrophylla*), and the former is superior for the manufacture of slender parts of furniture, such as the legs of chairs. It has been used for many years for the rails of boats and of late in the manufacture of very solid revolving chairs for deep-sea fishing. The rich, reddish brown Floridian mahogany is often specked with small black spots which disappear to some extent as the wood darkens with age. For many people the beauty of the wood is enhanced by these spots.

The flowers of the mahogany are inconspicuous, yet they ultimately produce pods the size of turkeys' eggs. These open from the bottom, shedding many winged seeds, which look like the seeds of a maple tree. Of all our trees, few are greater seed-producers and few can germinate and grow on rough, rocky soil as freely as the native mahogany. The winged seeds, rotating as they fall, are so retarded in their descent that they are widely spread by the wind. As cattle do not eat the bitter foliage of mahogany, it tends to gain ground in pastures.

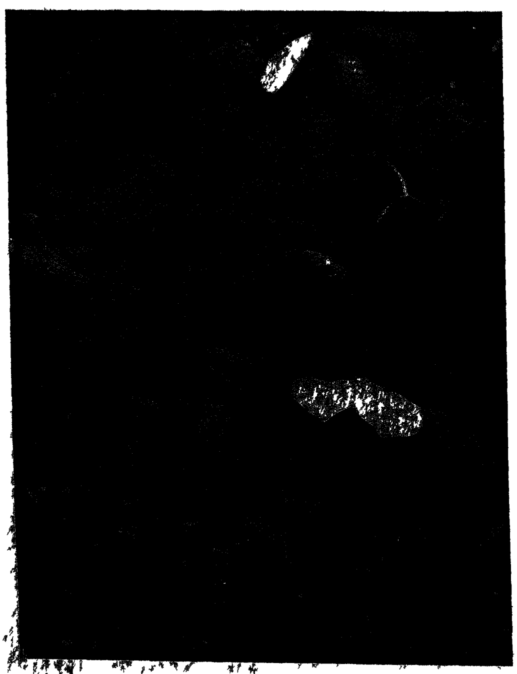
The mahogany tree is not so slow to grow as is ordinarily supposed. Hard, heavy wood does not necessarily mean slow growth. The northern black locust is a hard and heavy

wood and yet it is one of our quickest growers. I have known mahogany on mediocre soil in Florida close by the sea to add one inch in diameter each year. In rich, moist soil it is a fast grower with a broad spread of dense foliage. When growing in an uncrowded location, it has massive limbs. These limbs are unexcelled for the ribs of boats as well as for furniture, because a beautiful crotch grain occurs where the limbs join the trunk.

Mahogany is a yardstick for other woods, and the tree in urn compares favorably with the live oak for grace and sturdiness. After a recent cold snap some of the mahoganies on the mainland dropped their leaves. There soon followed a fine crop of pale green leaves, some tinged with red. This interruption in growth probably produced a distinct ring in the wood which would give it a variety of grain lacking in wood further south where growth is continuous.

Fishpoison-Tree

The fishpoison-tree, *Piscidia communis* (Blake) Harms, is more commonly known as the Jamaica-dogwood, but botanists reject the latter name because it is misleading.



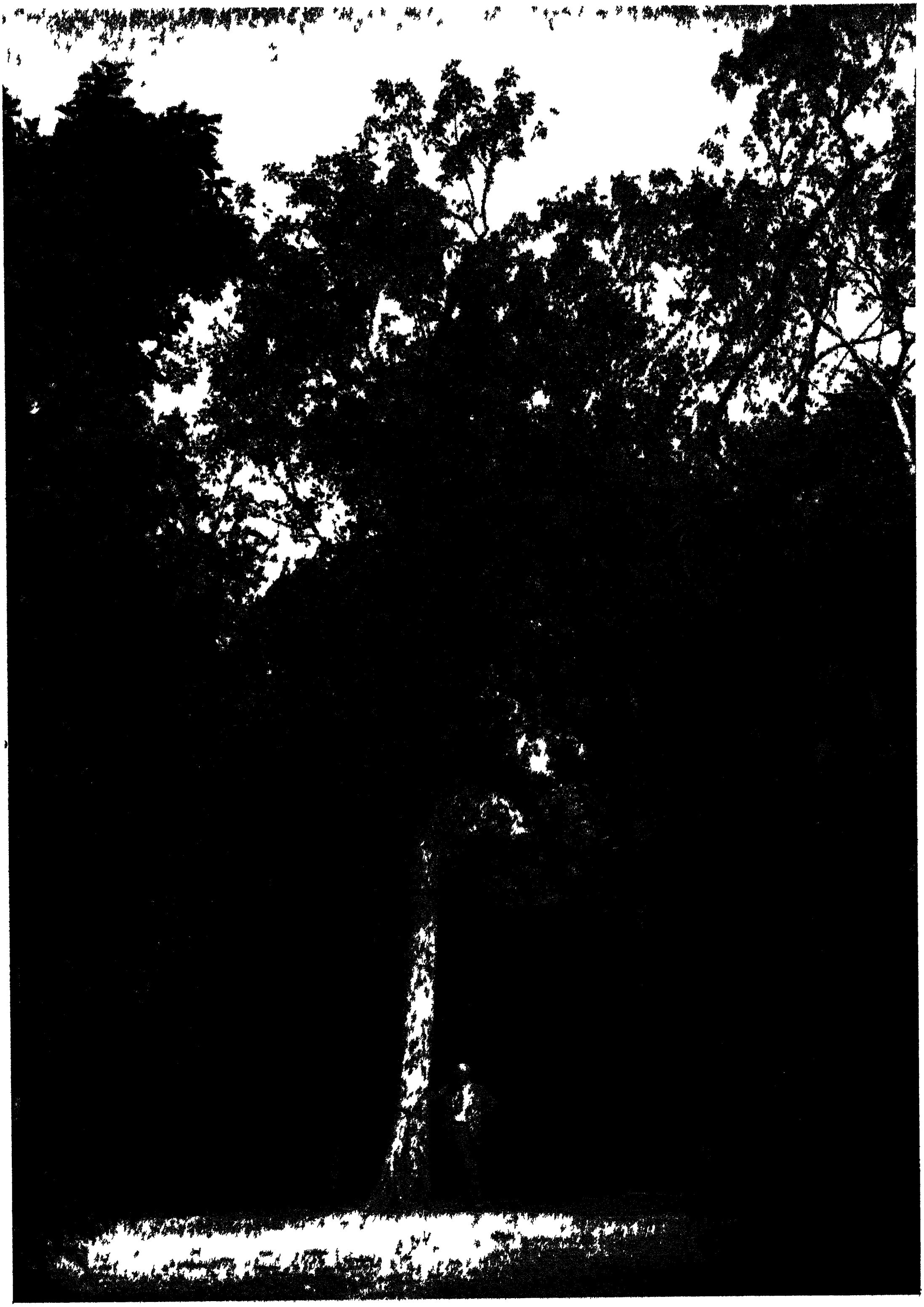
LEAVES OF THE FISHPOISON-TREE

Piscidia communis in no way resembles the well-known flowering dogwood, *Cornus florida*. Moreover, it does not really belong to Jamaica, since it is one of our commonest hammock trees and is found also in Yucatán. Trees were often named for the uses of the wood. As various pieces of wood used in implements and machines were called "dogs," any wood, regardless of botanical origin, that might be used as a "dog" could be called dogwood. However, botanists now prefer to restrict "dogwood" to species of *Cornus*.

As the name indicates, the fishpoison-tree has been used principally to stupify fish in order to catch them easily. The roots of a number of other tropical leguminous trees and shrubs have also been used for this purpose throughout the world The bark of the root is pounded into a pulp, put into a basket, and lowered into a fish hole. Sometimes it is merely thrown into the water. The fish soon come to the surface, inactivated by certain toxic substances washed from the bark. This practice was probably learned from the Indians. It does not kill the large fish but is fatal to the small ones. Although some fish-poisoning plants, such as derris and cube, have become important as sources of insecticides, the fishpoison-tree has not shown promise for this purpose.

The fishpoison-tree was much used years ago for timbers in boat construction. Once, on the keys, two brothers wanted a new boat. They had settled on Pensacola yellow pine for the planking, but could not agree on the kind of wood for the ribs. One insisted on "madeira," the Florida name for mahogany; the other insisted on "dogwood." I acted as mediator, and it was finally decided to put the ribs close together, alternating mahogany and "dogwood." Although that was twenty-five years ago, the boat still floats, and all the ribs are still solid. The fishpoison-tree will be important someday in the forestry of the tropics. The fact that it has been used for the ribs of boats, the fellies of wheels, and the frames of vehicles speaks for its strength and durability.

The fishpoison-tree has luxuriant leafage and bears masses of small, pea-like, white flowers tinged with red. The fruit consists of broad, four-winged, light-brown pods.



A FALSE-MASTIC TREE TOWERING IN MATHESON HAMMOCK

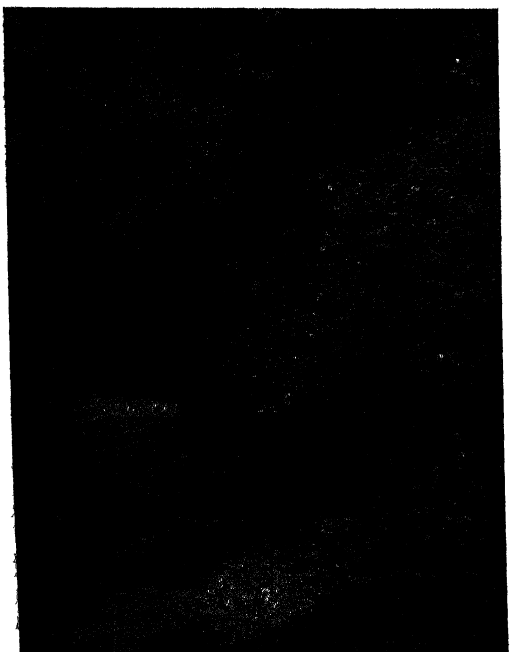
Regeneration is good in the regions where it is native and many seedlings are to be found in spite of cuttings and fires. There are two distinct forms of this tree in South Florida, hardly different enough to warrant the formation of another species.

FALSE-MASTIC

False-mastic (*Sideroxylon foetidissimum* Jacq.), like lignumvitae, yields a wood that is heavy enough to sink in water. The generic name means ironwood. "Mastic" in the common name indicates that this tree also yields a gum, which is found particularly in the fruits. The yellowish or orange wood of the false-mastic is hard, strong, and durable.

False-mastic grows in abundance in Snapper Creek Hammock and other hammocks in South Florida. I called these trees to the attention of Mr. W. J. Matheson. He was so much surprised and elated at the size of these "mastic" trees that he bought the land and willed it to the county. It is now a popular park known as Matheson Hammock.

The flowers of false-mastic are inconspicuous. The fruit, which is usually abundant in the spring, is about an inch long with a tough skin and thin flesh covering a seed about a half-inch in length. It is eaten by various animals but is not fit for human consumption. The bark is dark gray, sometimes light brown, forming in plate-like scales. The tree is usually tall and straight.



A HAMMOCK PATH, SIMPSON PARK
THE YOUNG TREES ON THE RIGHT ARE LIGNUMVITAE.

False-mastic extends northward on the east coast of Florida as far as Cape Canaveral and is common in Cuba and the Bahama Islands. This tree, in fact all trees here mentioned, are such good seed producers that any person desiring to produce these trees in quantity would have no trouble in finding seeds locally.

LIGNUMVITAE

Lignumvitae, the "wood of life," is so called because at one time the gum in its wood was considered one of the most valuable medicines of the world. The name of this resin, guaiacum, is also the generic name of lignumvitae (*Guaiacum sanctum* L.). Guaiacum is obtained by soaking the sawdust and chips in alcohol or ether. Tears of the resin exude from wounds on the living tree.

With the probable exception of leadwood or "Florida ironwood," *Krugiodendron ferreum* (Vahl) Urban, lignumvitae is the heaviest wood growing in the United States. It weighs about 80 pounds per cubic foot and has a specific gravity of 1.32.

One of the Florida keys is called Lignum Vitae Key because this tree was once plentiful there. I have found it on Big Pine Key, Key Largo, and other keys, but this interesting and valuable tree is rapidly passing. In the battle against axe and fire any tree must produce an immense amount of seed in order to survive. In spite of a constant demand, however, a tree now and then may be seen in secluded places. The wood is still sold by the pound and is probably the most valuable of all commercial woods. Because of its toughness there is probably no wood with a greater variety of special uses. Its earliest use was in the manufacture of sheaths for ship-blocks. In the days of sailing vessels these blocks were essential, and for many years the woods by tidewater in Florida were used for ship construction by at least three nations, not to mention pirates and other outlaws. Of all the special parts of a ship demanding special woods, none was more important than the ship's blocks, through which the ropes could run easily without the danger of

breaking under the great strain. Later in the days of steamships lignumvitae was used as bushings for lining the tubes of propeller shafts—a most important and exacting application. Today it serves for mallets, tenpin balls, castors for furniture, brush backs, and a host of similar uses. Its wood fibers are interlaced in such a way that it never splits.

The tree is short and stout. It occurs in the shade in mixture with other plants. It is of slow growth and in some places looks as tough as its wood. It is often fresh green when other plants have been seared by drought. Three or four flowers under an inch in diameter are produced at the ends of the branches. The color of these delicate flowers varies in shades of blue. The fruit is roundish, less than an inch in diameter, and is bright orange when ripe. Inside are black seeds covered with a scarlet coat.

As a plant for future landscape architecture and forestry in the tropics, it probably should have an important place. In the West Indies many lignumvitae trees persist, but in the State of Florida it will soon be a thing of the past unless preserved by those who are interested in useful native trees.

Treatment of Cabinet Woods

None of the foregoing cabinet woods should ever be painted or even stained, for their beauty is in their natural grain and color. The surface of the wood should be made as smooth as possible and then, if covered at all, should be coated with some transparent substance. "Elbow grease" is, after all, the best. Good seasoning is necessary, though not always understood even by experienced workers of wood. Sometimes the natives bury the wood in mud for several weeks to season by a process of osmosis, and then keep it for a long time in a dry, shady, airy place. The heartwood of old trees does not need much seasoning.

The ends of logs in piles are often painted to prevent too rapid evaporation. Planks of such wood are usually set up loosely on end against a wall and against each other to facilitate seasoning. This practice exposes all the wood to the air and facilitates even drying. A change from a warm to a cold climate often produces many small cracks in the wood, especially when the wood has not been perfectly seasoned. Many cabinet-workers have special methods for preparing woods for their particular work, but on the whole the main object seems to be to produce a slow, even process of seasoning over a considerable length of time. Wood dug out of the mud and muck in which it has been buried for many years is perfectly seasoned and very durable. Many of the old logs of mahogany and lysiloma buried in the debris of the forest are perfectly seasoned. In virgin forests where there have been windfalls and no fires, there are many such fallen trunks. In such cases it is usually only the heartwood that has escaped the termites. Many mahogany trees were cut from a scaffold far above the bulge at the base and in these old stumps there is still much well-seasoned wood with beautiful grain.

For many years private interests and government bureaus have been busy importing species of trees from abroad. This has been good work, and the results have warranted the cost and effort involved. Several of these introduced trees have become naturalized. Experimentation along this line, however, must cover a long period of time before conclusions are warranted. In the meantime we have neglected some of our native trees. Nature has done this experimentation for us. For that reason the forester should pick the best of our native trees, study their natural forest formation before it is too late, and proceed to apply the fundamental rules of forestry to what is left as soon as possible. For this purpose the five species mentioned in this article are unquestionably of great merit.

In some parts of the world where species of plants have become exceedingly rare, laws have been passed preventing their ruthless destruction, regardless of their location or ownership. This rule is applied even in this country to certain rare animals. Man gains title to wild land in various ways; he then builds fences and kills off whatever seems to oppose him. This so-called progress has sometimes resulted in a sacking of our inheritance. There is a vast difference between exploitation and true development.

CUTANEOUS LEISHMANIASIS IN MEXICO*

By ENRIQUE BELTRÁN

AN examination of the figures on pre-Spanish pottery found in certain parts of Peru reveals some very peculiar scars on a number of the human faces represented on them. These scars indicate the existence of a disease of ulcerous nature suffered by the ancient inhabitants of the powerful Inca Empire.

Such authorities as Professor Brumpt think that these pictures are unequivocal proof that there already existed in those distant times the disease known today in Peru as *uta* and *espundia,* in Brazil as "Baurú ulcer" or *ferida brava,* and in Mexico as "chicle-gatherers' ulcer." Apparently the northern limit of its geographical distribution is reached in Mexico.

If the disease itself is ancient, its characterization as a definite nosological entity and the clarification of its etiology are quite recent. Only in 1909 did Lindenberg, and Carini and Paranhos, all in Brazil, identify the "Baurú ulcer" or *ferida brava* with the so-called "Oriental button" or "Oriental ulcer" occurring in the hot, dry regions of the Old World, especially in the Mediterranean basin. Since the beginning of the century, a protozoan of the genus Mastigophora, named *Leishmania tropica* (Wright), 1903, has been considered the cause of the latter disease.

Those who first investigated it in the New World believed that the American disease was the same as that already known in Europe, Asia, and Africa; consequently, they supposed that the parasite found in the lesions was the same *Leishmania tropica.* In fact, the parasites of both are so similar that their morphological differentiation is impossible.

* Translated by Mr. Hurst K. Majors. The original Spanish text is published opposite on right hand pages. The illustrations are distributed between the Spanish and English texts. Grateful acknowledgment is made to Dr. A. A. Moll, Sanitary Bureau, Pan American Union, Washington, D. C., for his careful editorial examination of both the Spanish and English texts.

Nevertheless, Vianna, a Brazilian investigator, in consideration of the marked clinical differences observed in the American disease as compared with its course in the other hemisphere, believed it desirable to regard the Brazilian parasite as a new species, which, in 1911, he named *Leishmania brasiliensis.* This designation is now accepted by the majority of investigators who believe that they are dealing with a distinct species —a view reinforced by the studies on immunology carried out by Noguchi.

In that same year, 1911, Seidelin discovered cutaneous leishmaniasis in Mexico, while studying yellow fever in Yucatán, and published the first description of it that we know of from that country. It is reproduced here for its historical interest.

> I had, for a long time, been on the look out for the various forms of tropical ulcers, but failed to find any of a specific nature, until Mr. Th. Maler, an Austrian archaeologist, who has lived for nearly fifty years in Yucatán, told me about a peculiar affection which he had observed with great frequency during his travels in the interior. He said that the "chicleros," Indian labourers, who collect chicle (the raw material of chewing gum), suffered severely from a certain kind of ulcer, which always started on the external ear, often destroying it completely, and invading the face to a large extent. The natives did not, as a rule, apply for treatment, and even if they did, favourable results were but seldom obtained. . . . The disease is evidently met with in all parts of the peninsula, both in the interior of Yucatán, in Campeche and in Quintana Roo. Also many laymen knew the affection as a typical one, the "ear ulcer of the chicleros.". . . The parasites observed had the morphological characters of *Leishmania tropica;* they were mostly situated inside large mononuclear cells, from two or three to about twenty in a single cell.

More than thirty years have passed since this disease was made known in Mexico, but we are still ignorant of many of its aspects, despite the diverse but hardly numerous studies which have been made of it.

In the forested areas which account for two-thirds of the Yucatán peninsula one of the chief resources is the tree that is popularly called *chico zapote* (*Achras zapota*),

LA LEISHMANIASIS FORESTAL CUTÁNEA EN MÉXICO

POR ENRIQUE BELTRÁN

Examinando las figuras de cerámica prehispánica encontradas en ciertas partes del Perú, suelen verse en algunas de las caras humanas en ellas representadas, cicatrices muy peculiares, que indican la existencia de un padecimiento de naturaleza ulcerosa, en esos remotos habitantes del poderoso imperio de los Incas.

Autoridades, como el Profesor Brumpt (*1*), piensan que esas representaciones son pruebas inequívocas de que, en aquellos lejanos tiempos, existía ya la enfermedad hoy designada como "uta" y "espundia" en Perú, "úlcera de Baurú" o "ferida brava" en Brasil y "úlcera de los chicleros" en México que, al parecer, constituye el límite Norte de su distribución geográfica.

Pero si la existencia de la enfermedad es antigua, su caracterización como una entidad nosológica determinada y, sobre todo, el esclarecimiento de su etiología, son bastante recientes. Fué en 1909 cuando Lindenberg (*2*) por una parte, y Carini y Paranhos (*3*) por otra, todos en Brasil, identificaron la "úlcera de Baurú" o "ferida brava" con el llamado "botón de Oriente" o "úlcera oriental," existente en las regiones cálidas y secas del Viejo Mundo, especialmente en la cuenca del Mediterráneo y que, desde principios del siglo se consideraba causada por un protozoario del grupo de los Mastigóforos, cuya designación en la actualidad es *Leishmania tropica* (Wright), 1903.

Los primeros investigadores del Nuevo Continente pensaron que la enfermedad americana era la ya conocida en Europa, Asia y Africa y, en consecuencia, se supuso que el parásito encontrado en las lesiones era la misma *Leishmania tropica.* Y en efecto, los parásitos que se presentan en uno y otro casos son tan semejantes, que su diferenciación morfológica se hace imposible. Sin embargo, un investigador brasileño, Vianna, considerando las marcadas diferencias clínicas que se observan en el padecimiento del Nuevo Continente, comparado con el del Antiguo, pensó prudente individualizar el germen encontrado en Brasil, designándolo con el nombre de *Leishmania brasiliensis,* en el año de 1911; designación aceptada en la actualidad por la mayoría de los autores que piensan que, en efecto, se trata de una especie distinta, particularmente después de los estudios inmunológicos llevados a cabo por Noguchi (*4*).

En el propio año de 1911 Seidelin (*5*), estudiando la fiebre amarilla en Yucatán, México, encontró la leishmaniasis cutánea en nuestro país, y publicó la primera descripción de la misma de que tenemos noticia y que, por su interés histórico, cito *in extenso* a continuación:

> Por largo tiempo había estado buscando las varias formas de úlceras tropicales, sin encontrar ninguna de naturaleza específica hasta que el Sr. Th. Maler, arqueólogo austriaco que había vivido en Yucatán por cerca de cincuenta años, me habló de una enfermedad que había encontrado con gran frecuencia durante sus viajes en el interior. Decía que los "chicleros," trabajadores indígenas que colectan chicle (la materia prima de la goma de mascar) sufrían severamente de una cierta clase de úlcera, que siempre comenzaba en la oreja, destruyéndola a veces completamente, e invadiendo ampliamente la cara. Generalmente los nativos no buscaban tratamiento, y cuando lo hacían, solo rara vez obtenían resultados favorables. . . . La enfermedad se encuentra, evidentemente, en toda la península, tanto en el interior de Yucatán, como en Campeche y Quintana Roo. Aun los profanos conocen la enfermedad como típica: la "úlcera de la oreja de los chicleros." . . . Los parásitos observados tienen las características morfológicas de *Leishmania tropica;* se encuentran en su mayor parte dentro de los grandes mononucleares, en número desde dos o tres, hasta veinte en una sola célula.

Hace, pues, más de treinta años que se señaló esta interesante enfermedad en nuestro país y, sin embargo, hasta la fecha ignoramos aun muchos aspectos de ella, a pesar de las diversas contribuciones realizadas al respecto, no muy numerosas por cierto.

Foto Robles

CHICLE-GATHERERS' ULCER
LESION PRIMARIA, EN LA NARIZ, CAUSADA POR *Leishmania brasiliensis*, SIN TRATAMIENTO.

the sap of which, chicle, is the basic material used in the manufacture of chewing gum, a popular article in the United States and Mexico. The English common name of this tree is sapodilla.

Some remnants of the Mayan tribes, who populated the peninsula during ancient times and who constructed the great cities of Uxmal, Chichen Itza, Tulum, and others, live in the midst of these forests even yet as small groups. However, the number of permanent inhabitants is very low throughout the entire region.

The jungle population is made up for the most part of workers who contract to secure chicle or to cut down hardwoods. They are adventurers who bury themselves in the green hell of the jungle for months in order to seize its treasures.

The *chicleros*—some of them natives of Yucatán and others from other parts of Mexico—begin to penetrate the jungle at the close of the dry season. In the past they advanced in caravans to the heart of the forest along paths which had to be kept open with the machete; today, for the most part, they reach their jungle centers by air and then continue on foot in small groups to seek sapodilla trees in the forest.

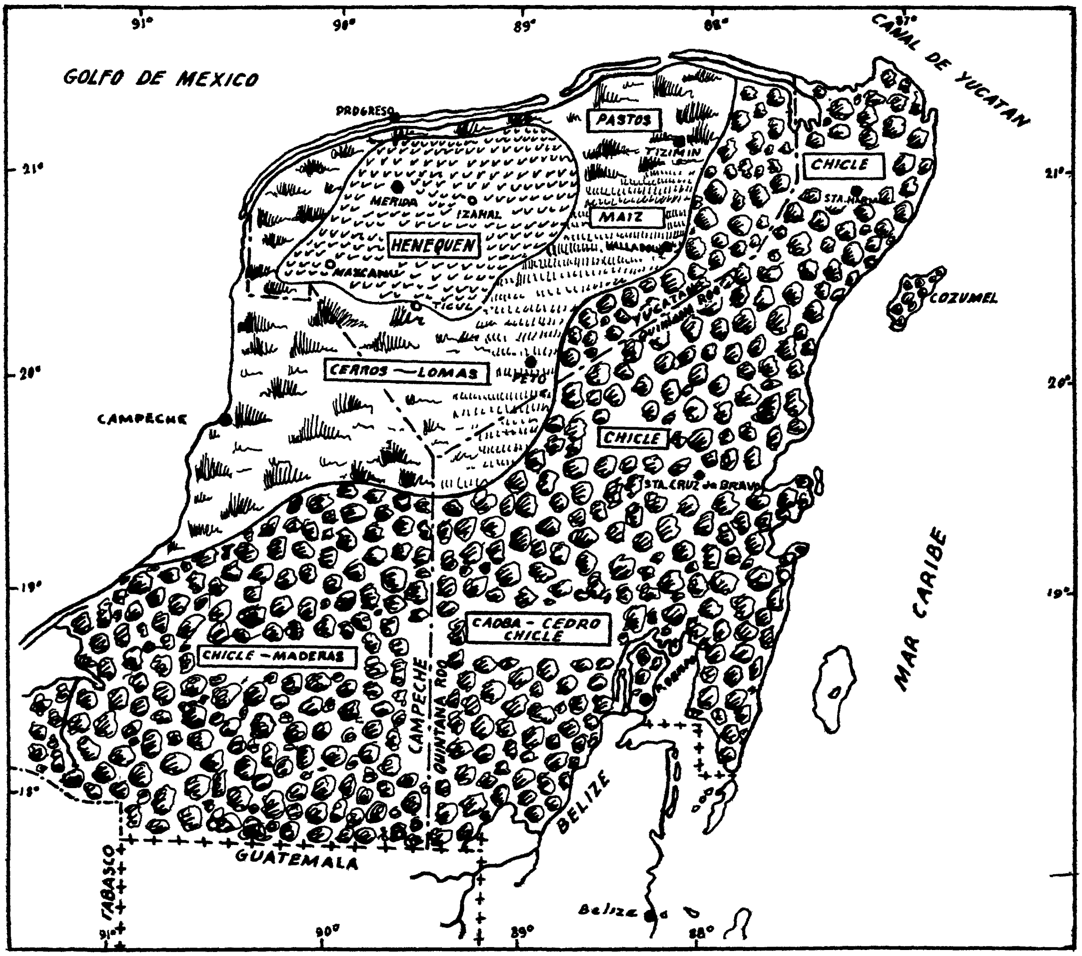
From our own investigations, which began in 1939, we have learned that of these groups of workers, mostly men but sometimes including wives and children, approximately 5 per cent end the season affected by forest leishmaniasis of the skin, the fearsome *chiclero* ulcer.

In South America, and especially in Brazil where most of the work on this disease has been done, the disease begins in an almost imperceptible fashion. An individual finds on one of the exposed parts of his body (in Brazil, usually the legs) a small reddened area, similar to that which results from the bite of one of the many jungle insects; the fierce itching which he experiences forces him to scratch himself repeatedly. Gradually a small papule is formed, and then a little nodule, the surface of which soon ulcerates, forming a scab. Then *Leishmania* with the help of other associated infections rapidly destroy the tissues. When the lesions occur on the legs, arms, chest, or back, the course of the affliction, although troublesome and destructive, is without serious consequences. It is different if the ulcers occur on the face. Not only is a deforming scar left, but a considerable number of cases experience an infection of the mucous membranes of the nose and mouth. In such an event, the course of the disease is more serious.

Brazilian writers suspect that the vectors of the American disease are different species of small flies belonging to the genus *Phlebotomus,* in conformity with the widely accepted idea that similar Old World leishmaniases are transmitted by the same insects. The evidence advanced in support of this theory is most interesting, and all possibilities seem to point in this direction. Nonetheless, conclusive proofs are lacking which would permit calling *Phlebotomus* a vector of this disease with the same certainty with which we can connect *Anopheles* with malaria or *Aedes* with yellow fever.

In Mexico, according to the little that we know about it, the disease begins and main-

En las zonas boscosas que cubren las dos terceras partes de la península de Yucatán, existe como una de las principales riquezas de la región el árbol llamado vulgarmente "chico zapote" (*Achras zapota*) cuyo latex,



Mapa de la Sria. de Agricultura y Fomento, México

FORESTED AREAS OF YUCATÁN WHERE CUTANEOUS LEISHMANIASIS OCCURS

ZONAS AGRÍCOLAS Y FORESTALES DE LA PENÍNSULA DE YUCATÁN. LA REGIÓN BOSCOSA ES EL ASIENTO DE LA LEISHMANIASIS CUTÁNEA.

el chicle, sirve de materia prima para la elaboración de la goma de mascar, tan popular en los Estados Unidos y en nuestro país.

Restos mermados de las tribus mayas que antaño poblaron la península, y que construyeron las grandiosas ciudades de Uxmal, Chichen Itza, Tulum y tantas más, viven aun, en pequeños grupos en el centro de esas selvas. Pero la cantidad de habitantes permanente es bajísima en toda la zona.

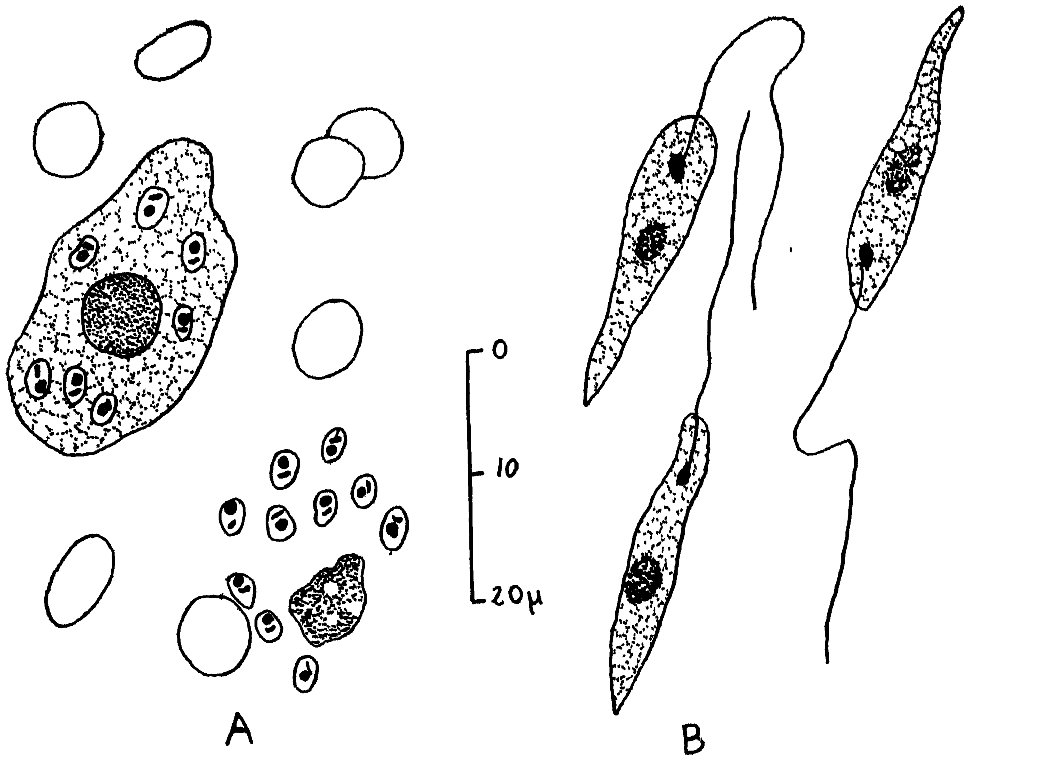
La población de los bosques la constituyen, en su mayor parte, trabajadores que van contratados a la extracción del chicle o al corte de las maderas preciosas, seres aventureros que se internan en el infierno verde de la selva, en el que se pierden por varios meses, para robarle al bosque sus tesoros.

A fines del verano empiezan a llegar a la selva los chicleros, nativos algunos de la propia península y otros procedentes de diversas partes del país. Antaño arribaban en caravanas por senderos en el corazón de la jungla, que frecuentemente hay que mantener abiertos a fuerza de "machete"; hoy, en gran parte, son transportados en avión

tains a course similar to that observed in Brazil, but there are certain interesting differences. In the first place, the point of origin for the first lesions is the ears; all writers from Seidelin to the present day are agreed on this fact. In 1940, in the recently concluded epidemiological investigation, more than 80 per cent of the reported cases were localized in the earlobes. However, Professor Osorio Tafall this year visited some *chiclero* camps in Quintana Roo and brought back the interesting observation (personal communication, unpublished) that in the last two seasons the number of cases localized on the ears had diminished considerably, at least in the area visited, because the *chicleros* had begun to wear at their work a sort of leather helmet which covered their head, ears, and part of their neck, throat, and shoulders. Even those workers who did not take this care were acquiring the habit of wrapping a protective cloth around the head in the manner already indicated. Although the real value of such head protection remains to be determined statistically, the practice offers grounds for interesting speculations.

Chicle-workers' camps or *hatos* are hidden away in the very heart of the jungle. A small clearing bordered by sapodilla trees (*Achras zapota*), mahogany trees (*Swietenia mahagoni*), rubber trees (*Castilloa elastica*), and a thousand other plants serves as a site for several dwellings with palmleaf (*Inodes japa*) roofs. Supported by upright timbers and frequently without walls, these shelters naturally afford no protection against insects.

The few women and children of the group remain in these camps at all times. Very early in the morning, the men go forth to search out chicle trees that are ready for tapping. If a good quantity of chicle is desired without killing the trees, tapping cannot be done unless the plants have reached a certain age and have not been tapped for at least five years. On finding a suitable tree, the *chiclero* climbs to its top with the help of a



Dibujo Beltrán

***LEISHMANIA BRASILIENSIS*: A, FROM AN ULCER; B, FROM CULTURE MEDIUM**

FORMAS EN UN FROTIS DE ULCERA. B. FORMAS FLAGELADAS EN CULTIVO EN MEDIO DE AGAR-SANGRE.

hasta las centrales y de ahí, a pie y en pequeños grupos, se internan a buscar los árboles de zapote que crecen silvestres en el bosque.

En nuestras investigaciones personales, iniciadas en el año de 1939 (*6*), hemos obtenido el dato que, de esos conjuntos de trabajadores, en su mayoría hombres, pero a los que también acompañan algunas mujeres y niños, aproximadamente el 5% regresa de la temporada afectado por la leishmaniasis forestal cutánea, la temida úlcera de los chicleros.

En Sur América, especialmente en el Brasil, donde se ha realizado el mayor número de trabajos al respecto, la enfermedad comienza en una forma casi imperceptible (*7*). El individuo nota en alguna de las partes descubiertas de su cuerpo (en aquel país predominantemente en los miembros inferiores) una pequeña zona enrojecida, semejante al piquete de alguno de los muchos insectos del bosque; la fuerte comezón que experimenta le obliga a rascarse repetidamente. Poco a poco se forma una pequeña pápula, luego un nodulito, que al poco tiempo se úlcera en su superficie, forma una costra y, sirviendo a la vez de asiento a otras infecciones asociadas, va avanzando realizando una labor de destrucción de los tejidos. Cuando las lesiones se encuentran en zonas como las piernas o los brazos, el pecho o la espalda, su evolución, aunque molesta y destructora, no suele ser de consecuencias. Cuando las úlceras están en la cara, el caso es distinto; no solo dejarán una cicatriz deformante sino que, además, en un crecido número de casos las mucosas de la nariz y de la boca serán también invadidas y, en tales ocasiones, la evolución del padecimiento es más seria.

Los autores brasileños (*8*) suponen que son pequeños moscos del género *Phlebotomus* (distintas especies), los que sirven de vectores a la enfermedad. Confirmando así la idea bastante aceptada de que las leishmaniasis del Viejo Continente son transmitidas por los mismos insectos. Las evidencias aducidas en apoyo de esa suposición son muy interesantes, y todas las posibilidades parecen apuntar en esa dirección. Sin embargo, faltan aun pruebas concluyentes que permitan acreditar el papel de transmisores a los *Phlebotomus*, con la misma seguridad que puede achacárseles a los *Anopheles* en el paludismo, o a los *Aedes* en la fiebre amarilla.

En México, de acuerdo con lo poco que sabemos al respecto, la enfermedad empieza y tiene una evolución semejante a la observada en Brasil, notándose sin embargo algunas interesantes discrepancias. En primer lugar, el sitio de elección para la aparición de las lesiones primarias lo constituyen las orejas; concordando en esto las observaciones de todos los autores, desde Seidelín para acá. En 1940, en la encuesta epidemiológica que llevamos a cabo, más del 80% de los casos reportados tenían su localización en el pabellón de la oreja. Sin embargo, en el presente año nuestro estimado amigo el Profesor Osorio Tafall, realizó una visita a algunos de los campos chicleros de Quintana Roo (datos no publicados), recogiendo la interesante observación, que bondadosamente nos ha comunicado de que, en estas dos últimas temporadas, el número de casos con localización en la oreja ha disminuído considerablemente, a lo menos en la región visitada por él, debido a que los chicleros han adoptado la costumbre de usar en su trabajo una especie de casco de cuero que les cubre la cabeza, las orejas, y parte de la nuca, los carrillos y el cuello; quienes no poseen esa prenda, están, sin embargo, adquiriendo el hábito de protegerse igualmente empleando alguna tela, con la que se envuelven la cabeza en la forma indicada. Este dato, que necesita una verificación estadística para encontrar su real valor, es muy interesante por las diversas sugestiones que de él parecen desprenderse.

Los campos o "hatos" chicleros están enclavados en el corazón mismo de la selva. Un pequeño claro, bordeado de zapotes (*Achras zapota*), de caobas (*Swietenia mahagoni*), de hule (*Castilloa elastica*) y de mil otras plantas, sirve de asiento a unos cuantos cobertizos con techo de palma de guano (*Inodes japa*), sostenidos por palos rectos, frecuentemente sin paredes y, naturalmente, sin elemento alguno de protección contra los insectos.

En dichos campos está permanentemente el pequeño número de mujeres y niños del grupo. En cuanto a los hombres, desde muy temprano, salen en busca de árboles de chicle

rope. Afterwards, he climbs down slowly, always aided by the rope which he holds with the left hand, meanwhile making oblique slashes with the machete carried in his right hand. These slashes are so placed that the greater part of them follow a definite herringbone pattern, each emptying into the opposite one below and leading to the foot of the trunk. Here there is placed a suitable container—generally a canvas bucket—which catches the sap that runs slowly from the wounds in the bark.

Each day's yield is carried to camp and dumped into great copper kettles that are placed on the fire to cook the chicle. In this manner are secured cakes of a definite size which are carried to the markets and for which the *chiclero* is paid by the pound.

Living in a damp and stifling climate characterized by heavy rains, exposed to the bites of a great variety of poisonous snakes, and eating an unbalanced and insufficient diet which must be supplemented with the meat of animals hunted in the forest, the *chiclero* stays in the jungle for three to six months at a time. No small percentage of the workers who return carry on their bodies the peculiar and tenacious ulcers caused by *Leishmania brasiliensis*.

At present, the injection of various antimony preparations (*Stibosan*, *Neostibosan*, *Fouadin*, etc.), which are highly effective in cases of leishmaniasis, has permitted a certain curative control of this disease. The *chiclero*, if he secures treatment in time, generally succeeds in halting the disease. With the rise of chemical therapy one sees less frequently those poor mutilated persons who lack part of an ear, an entire ear, and sometimes both ears, and who have the appearance of being victims of that medieval justice which used to punish certain crimes by amputating an ear.

Although there exist isolated and unconfirmed reports that suspected autochthonous cases of skin leishmaniasis have been found in other parts of Mexico, the only region where its presence has been established is in wooded parts of the Yucatán peninsula (the states of Yucatán and Campeche and the ter-

Foto Beltrán

A CHICLEROS' CAMP OR HATO IN QUINTANA ROO. SAPODILLA TREE IN CENTER

ASPECTO DE UN CAMPO O "HATO" CHICLERO EN QUINTANA ROO. EN EL CENTRO UN ÁRBOL DE CHICO-ZAPOTE.

propios para ser "picados," cosa que no puede hacerse sino en plantas de cierta edad y dejando transcurrir un término mínimo de cinco años entre cada "picada," si es que se quiere tener una buena cosecha de chicle y conservar la vida del árbol. Cuando encuentran uno adecuado trepan hasta su cúspide con la ayuda de una cuerda y después van bajando lentamente, siempre auxiliados con la cuerda que manejan con la mano izquierda, mientras con la derecha hacen cortes oblicuos con el "machete," de tal manera dirigidos que el superior vierte su contenido en el que le sigue y que tiene dirección opuesta, hasta llegar al pie del tronco donde colocan un recipiente adecuado, generalmente una bolsa de lona, para recibir el latex que va escurriendo lentamente por las heridas de la corteza.

La cosecha de cada día es llevada al campamento y reunida en grandes pailas de cobre, que se ponen al fuego para cocer el chicle y obtener de ese modo marquetas de determinado tamaño, que son las que se entregan en las centrales y cuyo pago se hace por peso al chiclero que las obtuvo.

En un clima húmedo y sofocante, con fuertes lluvias, expuesto a las mordeduras de gran variedad de serpientes venenosas, con una alimentación insuficiente y desbalanceada, que tiene que completar con los animales que caza en el bosque, el chiclero permanence en la selva por un término que varía de tres a seis meses, Y los que regresan, en no pequeño porcentaje, llevan en su cuerpo las peculiares y tenaces úlceras causadas por la *Leishmania brasiliensis*.

A la fecha, el uso de las diversas preparaciones inyectables a base de antimonio (Stibosán, Neostibosán, Fuadina, etc.), cuya acción en las distintas leishmaniasis es sumamente efectiva, han permitido un cierto control curativo sobre esta enfermedad. El chiclero, si se trata a tiempo, generalmente logra que se detenga el padecimiento, y cada día es menos frecuente ver esos pobres mutilados a quienes falta parte de una oreja, la oreja, entera, y a veces ambas orejas, lo que les da la apariencia de ser víctimas de aquella justicia medioeval que castigaba ciertos delitos con la amputación del pabellón auditivo.

Aunque existen reportes aislados y no comprobados, de supuestos casos autóctonos de leishmaniasis cutánea encontrados en diversos sitios del país, la única zona donde ha sido establecida la presencia de este padecimiento es en las partes boscosas de la península de Yucatán (Estados de Yucatán y Campeche y Territorio de Quintana Roo) y en

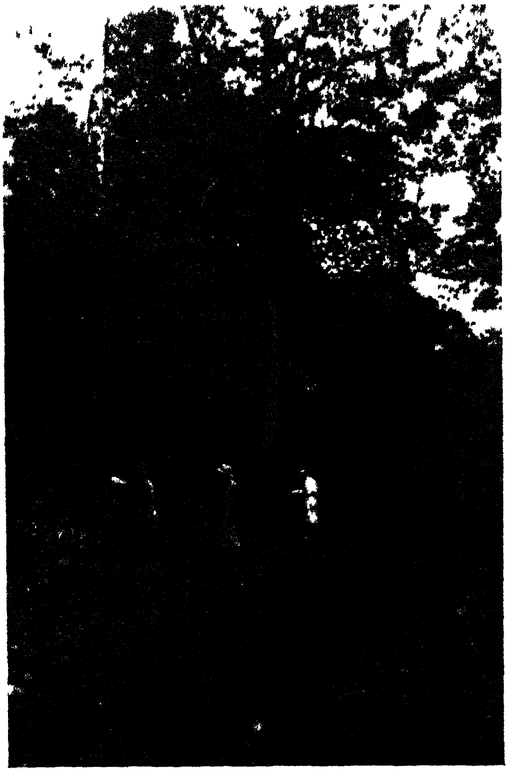


Foto Beltrán

THE JUNGLE, QUINTANA ROO

ASPECTO DEL BOSQUE EN LA REGIÓN DE BACALAR, QUINTANA ROO. AL FONDO EL DR. ROBERT HEGNER, FRENTE A UN ÁRBOL DE CHICO-ZAPOTE (*Achras zapota*).

las partes limítrofes de los Estados de Chiapas y Tabasco (*9*). Sin embargo, muy recientemente, por cortesía de los Drs. Martínez Báez y González (datos no publicados), tuvimos oportunidad de ver un caso de leishmaniasis cutánea en un niño (cuyo diagnóstico se comprobó microscópicamente), nativo de Huajuapan de León, Oaxaca, y que, según los datos disponibles, nunca había abandonado su residencia. Este hallazgo, sobre cuya significación no podríamos pronunciarnos antes de hacer un estudio que tenemos proyectado, es por demás interesante no sólo

ritory of Quintana Roo) and in neighboring areas of the states of Chiapas and Tabasco. Very recently, however, through the courtesy of Drs Martínez Báez and González (data unpublished), we had the opportunity of seeing a microscopically confirmed case of skin leishmaniasis in a boy, a native of Huajuapan de León in Oaxaca who, according to information available, had never been away from home This discovery, the significance of which I cannot judge until I have carried out a projected study, is interesting not only because the case was found more than 600 kilometers from the zone of classic leishmaniasis, but also because the characteristics of the region, at 1,597 meters altitude and with a dry climate, are absolutely different both physiographically and biologically from those of the southeastern jungles.

Given the geographical limitation of the disease, its relatively benign form in Mexico (it is much less grave here than in Brazil), and the existence of drugs of sufficient effectiveness to treat it, it cannot be said that forest leishmaniasis of the skin amounts to a first-rank public health problem in Mexico. However, it has a number of aspects which give it great scientific interest.

In Mexico lies the northern limit of the continental distribution of the disease. Consequently, it follows that it is highly important to establish the exact limits of its distribution there. It is equally important to define more closely the characteristics of the infection and of its etiological agent, comparing them with the findings in the republics to the south. It can also be stated that a series of clinical differences exist which would justify this study.

Its method of transmission in Mexico is not yet known. The inhabitants of the affected region generally assign the role of vector to the so-called *mosca chiclera* or "chiclero fly" (*Olfersia coriacea*), which attacks various gallinaceous birds in that region, and even Bequaert has been led to mention this as possible. However, our own

Foto Beltrán

THE AUTHOR (LEFT) AND DR. HEWITT STANDING BEFORE A CHICLERO'S HUT

CHOZA DE CHICLEROS, TECHADA CON PALMA DE GUANO (*Inodes japa*). AL FRENTE, EL DR. REDGINAL HEWITT (CON CASCO) Y EL AUTOR.

porque el sitio está a más de 600 kilómetros de los límites de la zona leishmaniásica clásica, sino porque las condiciones de la región, a 1,597 metros de altura y con un clima seco, son absolutamente diferentes de las de los bosques del sureste, tanto fisiográfica como biológicamente.

Dada la limitación geográfica del padecimiento, la forma relativamente benigna que toma entre nosotros (mucho menos grave que en el Brasil) y la existencia de productos terapeúticos de bastante eficiencia para su tratamiento, no puede decirse que la leishmaniasis forestal cutánea constituya en México un problema sanitario de primera importancia. Sin embargo, existen una serie de aspectos que le dan gran interés científico.

México constituye el límite septentrional de la distribución continental de la enfermedad y, en consecuencia, resulta de la mayor importancia establecer los límites exactos de su área en nuestro país. Es igualmente importante precisar mejor las características del padecimiento y de su agente etiológico, comparándolas con las bastante conocidas que presenta en las Repúblicas del Sur. Desde luego, puede decirse que existen una serie de diferencias clínicas que justifican este estudio.

Su mecanismo de transmisión no es aun conocido en México. Los habitantes de la región atribuyen generalmente el papel de vector a la llamada "mosca chiclera" (*Olfersia coriacea*) que parasita en diversos gallináceos de la región, y aun Bequaert (*10*) ha llegado a mencionarla como posible; sin embargo nuestras observaciones realizadas en la zona chiclera nos inclinan a no considerarla con tal carácter. Aunque no está probado, puede considerarse como probable que los *Phlebotomus* sean sus transmisores, tal como se supone en Brasil, donde aun se han señalado las especies que parecen más sospechosas.

Su aparente preferencia por el sexo masculino adulto (los casos en niños y en mujeres son en menor porcentaje) constituye otro asunto de gran interés para ser investigado, tanto desde el punto de vista epidemiológico como experimental, tratando de aclarar si, como generalmente se supone, ello se debe únicamente a la mayor exposición por parte de los hombres, o existe algún otro factor que interviene en el asunto.

El estudio de los problemas inmunológicos, tanto de reacciones diagnósticas intradérmicas u otras, como de la aplicación de vacunas, iniciado con éxito en Brasil, presenta entre nosotros un campo virgen en el que pueden obtenerse muchos resultados, tanto científicos como prácticos.

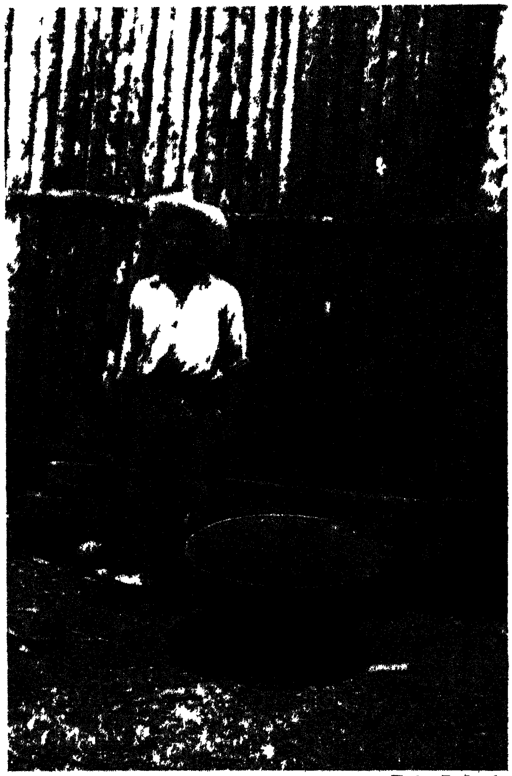


Foto Beltrán

CHICLERO AND CHICLE PAN

TIPO DE "CHICLERO" DE LA ZONA DE QUINTANA ROO. JUNTO A ÉL LA PAILA DE COBRE EN QUE CUECEN EL CHICLE.

La relativa facilidad con que se obtienen y mantienen cultivos vigorosos de estos protozoarios en medios de agar y sangre, ofrece un amplio campo de experimentación muy interesante, y que todavía tiene una serie de puntos por investigar.

Por otra parte, los datos que hasta la fecha existen con respecto a la susceptibilidad de diversos animales capaces de ser empleados

observations in the *chiclero* zone lead us to discount this view. Although it is not proved, it can be considered probable that *Phlebotomus* is the carrier, as supposed in Brazil, where the most suspicious species have already been signaled out.

The apparently greater incidence of the disease in adult males (only a small percentage of cases occur in women or children) constitutes another aspect of great investigative interest from the epidemiological, as well as experimental, viewpoint. It would be interesting to ascertain if, as generally supposed, this is due solely to the greater exposure on the part of the men, or whether some other factor enters into it.

Immunological problems, like diagnostic skin tests and the use of vaccines, already begun with success in Brazil, present in Mexico a virgin field in which many scientific and practical results may be obtained.

The relative ease with which these protozoa may be started and maintained as vigorous cultures in media of agar and blood offers an ample field for very interesting experimentation on a number of points which still require investigation.

Unfortunately, the present data on the susceptibility of the various animals that may be used with confidence in laboratory projects are contradictory. This is true even of the Syrian hamster (*Cricetus auratus*), which has not proved as good an experimental host to leishmaniasis of the skin as it was to visceral leishmaniasis. On the other hand, various squirrels and related species (*Citellus, Sciurus*, etc.) that are native to North America appear to offer possibilities in this field.

Therefore, although forest leishmaniasis of the skin cannot rank in Mexico with malaria, amoebic dysentery, onchocerciasis, and other parasitical diseases in public health importance, it is of enormous interest from the scientific point of view.

The emergency conditions now existing throughout America have shown us in an inescapable manner the stern necessity of understanding better all our native diseases, including their etiological, epidemiological, clinical, pathological, therapeutic, and immunological aspects. This need is even greater with respect to those diseases which, hidden in the jungle, conceal their real importance until the necessities of the moment, such as troop movements, road building, airfield construction, or the utilization of new zones of production, make us realize that even today there is much we do not know about vast territories in this immense hemisphere that now fights for its liberty and its future.

con confianza en los trabajos de laboratorio son contradictorios. Y esto es cierto aun en el caso del "hamster" de Siria (*Cricetus auratus*) que en la leishmaniasis cutánea no ha resultado ser tan buen huésped experimental como en el de la leishmaniasis visceral. En cambio, diversas ardillas y sus parientes (*Citellus, Sciurus,* etc) nativos de nuestro Continente, parecen presentar posibilidades en este sentido.

Así pues, si por su importancia sanitaria la leishmaniasis forestal cutánea en México no puede compararse con el paludismo, la amibiasis, la onchocerciasis y otros padecimientos parasitarios, desde el punto de vista científico presenta un enorme interés.

Las actuales condiciones de emergencia en que vivimos en todo el Continente nos han marcado, en forma ineludible, la necesidad absoluta que tenemos de conocer mejor todas aquellas enfermedades que nos son propias, enfocándolas desde los puntos de vista epidemiológico, etiológico, clínico, patológico, terapeútico, inmunológico, etc. Y esta necesidad es quizá mayor en el caso de aquellos padecimientos que, escondidos en la selva, suelen parar inadvertidos en su real importancia, hasta que necesidades del momento como transporte de tropas, construcción de caminos o campos de aterrizaje, utilización de nuevas zonas de producción, etc., nos hacen comprender que hay todavía mucho que ignoramos en las vastas tierras de este inmenso Hemisferio, que hoy lucha por su libertad y su futuro.

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THE EARLIEST WINGED FISH-CATCHERS

By E. W. GUDGER

SINCE birds are the best known winged fish-catchers, the title may conjure up a vision of small flocks of gulls of our northern harbors busily at work getting their dinners; or it may recall the far larger flocks of fish-catchers (terns, cormorants, and pelicans) which populate the keys of southern Florida. But, to see such winged fish-catchers in really surpassing numbers, one must go with Robert Cushman Murphy to his *Bird Islands of Peru*. If one cannot see these wondrous bird haunts in person, then one can at least envisage them in his most interesting and informative book just named (New York, 1925).

Around these Peruvian islands, which though inside the tropics are cooled by the north-flowing Humboldt Current, are found small fishes, especially anchovies, in such astronomical numbers as to defy computation. Feeding on these are marine birds in clouds darkening the sky from which they "descend in rainstorms" to merge on the surface in great rafts, covering acres and acres of ocean—areas so large that they are visible miles away. These millions of birds with insatiable appetites devour billions of fishes each day. Murphy estimates that "Thousands of tons of these fishes per day are devoured by sea birds which breed on the Peruvian islands." And earlier than he, R. E. Coker judged that a single flock of cormorants observed at the Cincha Islands would consume each year a weight of these fishes equal to one-fourth the entire annual catch of the fisheries of the United States.

These feathered fishermen are, however, the latest forms of all winged fish-catchers; to describe the earliest is the purpose of this article. These feather-winged ones are the highest developed in structure, activities, and numbers of all winged fish-feeders. In each of these points they are far removed from those creatures, buoyed on leathern wings, that sought their ichthyological dinners in the bays and seas of Mesozoic or middle geological time. In fact these earliest winged fishers were not birds at all, nor even the ancestors of birds, but in time and structure were far removed from them. They were the winged dragons of the Jurassic period. And after them came the toothed birds of the Cretaceous.

THE PTEROSAURS OR FLYING LIZARDS OF THE JURASSIC PERIOD

The pterosaurs (ter-o-sawrs) were, as their name indicates, winged lizards. They are also sometimes called ornithosaurs (or-ni-tho-sawrs) or bird-lizards, because they could soar like birds; but they were reptiles adapted for flight. Like some birds they had long beaks but their jaws were toothed. These pterosaur teeth were reptilian, being sharp, conical, and implanted in the jaws. Moreover, they were in all respects organs for grasping, like the long, pointed, rather slender, backwardly hooked teeth of the fish-eating crocodiles of the Ganges. Being carnivorous, these flying dragons had to eat either fishes or other reptiles, and their teeth indicate a fish diet.

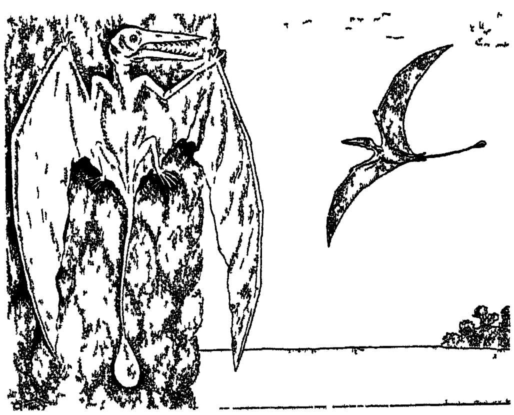
They flew somewhat like birds, and their general birdlike appearance was accentuated by the fact that the head was set on top of the spinal column almost at a right angle to the neck. Their forelimbs were adapted for a birdlike flight, the outer or fifth finger being enormously elongated into a boom or yard, the other fingers being free. From front leg and "little finger" there extended back along, and attached to, the side of the body the membranous wing, which included the hind limb, except the foot. The opposite wings joined on the tail (Fig. 1).

The pterosaurs were the most highly specialized of all backboned animals. As in birds, all the bones of the body were hollow and were lighter in structure than in any animals present or past, birds not excepted. In some forms the walls of the bones were as thin as a desk blotter. These had their extremities strengthened internally by delicate paper-thin struts of bone. All these light bones, like those of our present-day birds,

had openings that permitted the circulation of air. This structure gave these flying dragons an almost unbelievable lightness of body, as we shall see later. The surface area of their wings was, when compared with the weight of their bodies, greater than that of any other flying animals past or present, save only some of the insects.

Because of their enormously elongated outer fingers and the wings which they supported, these flying lizards got their common name, "wing-fingers." These pterosaurs varied widely in size—from that of a sparrow to giants of eight feet in length with a wing-spread of twenty feet. With bodies lightened by their thin-walled bones, they careered on leathern wings above the bogs, swamps, lakes, and seas of the Mesozoic era of the earth's far distant past, seeking what they might devour (Fig 1).

However, the best authorities agree that the power of flight in these dragons of the air was much more limited than in birds. There is great doubt as to the ability of the pterosaurs to fly by flapping their wings. The structure of their skeletons did not offer points of attachment for the great muscles necessary for prolonged flight by beating the air. Perhaps, however, they could flap their wings enough to help get a start for soaring flight. The paleontologists think that the pterosaurs were gliders and soarers, taking advantage of ascending air currents as do our gliders today. But then comes the question of the take-off. If they alighted on trees



After Fenton, 1937

FIG. 1. RHAMPHORHYNCHUS

ONE CLINGS TO BARK OF A TREE WITH CLAWED FEET; ANOTHER SOARS OVER A LAKE ON WIDESPREAD WINGS.

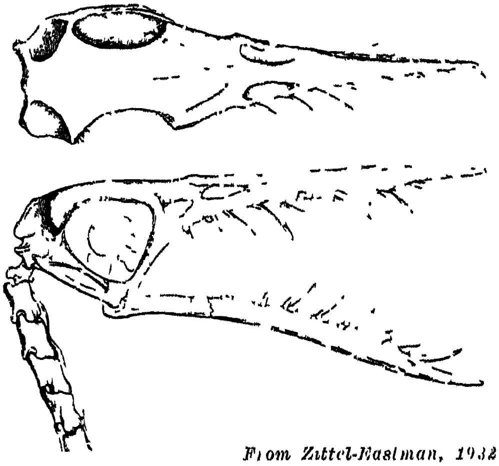
From a drawing in American Museum

FIG. 2. RHAMPHORHYNCHUS AT REST

FROM ITS PERCH IT COULD TAKE OFF, GLIDE, SOAR. AS ILLUSTRATED, THE BEAK IS TOO SHORT OR THICK.

or cliffs or any sharp elevation, they might launch forth fairly easily. But, if they should light on level ground or on the surface of the sea, how could they ever get up again? They were poorly adapted for walking, perhaps better for climbing by means of their clawed feet. So betwixt climbing and scrambling, they may have ascended trees and rocky declivities to where a take-off was possible, after the fashion of any gliding bird of today (Figs. 1 and 2). However, fly they did, since, even more than birds, they were fitted only for an aerial life.

These strange flying lizards, the most highly specialized and extraordinary animals that have ever lived on our earth, appeared suddenly in the Upper Triassic of Europe about 150 millions of years ago. Widely scattered over the earth, they flourished for millions of years and as suddenly as they appeared so suddenly they disappeared toward the close of the Cretaceous period, about 60 million years ago. In consonance with their extraordinary physical make-up are the equally extraordinary facts that they



From Zittel-Eastman, 1932

FIG. 3. SKULL OF CROOKED BEAK
THE HEAD IS AT A RIGHT ANGLE TO THE SPINE AND THE IRREGULAR TEETH POINT OUTWARD AND FORWARD.

came without known ancestors and became extinct without leaving descendants.

There were numerous genera and species of these flying dragons. The earlier ones had long lizard-like tails; the later forms had vestigial tails and were probably the better fliers. Certainly among them were the largest flying animals the world has ever seen. For food possibly (indeed probably) all of them, among other edible things, caught and ate fishes as is indicated by the structure of their teeth. Our attention will be concentrated on the three well-known forms —Rhamphorhynchus, Pterodactylus, and Pteranodon—all surely fish-catchers.

Rhamphorhynchus (ram fo-rin'-cus) or Crooked Beak, so called probably because of his strangely set teeth (Figs. 1, 2, and 3), was a relatively small flying lizard (about 1½ feet long) notable for having long, narrow, pointed wings like those of a gull or a tern, and a long slender tail ending in a spatulate organ which probably functioned as a rudder (Figs. 1 and 4). The position of this rudder, whether horizontal or vertical, has been much discussed. This unique structure was long held to have had a vertical position like the tail or rudder of an airplane, but a leading authority has concluded, from a critical study of the best material, that it was horizontal as is the tail in all other flying animals, save the so-called flying fishes.

Equally characteristic were the long pointed jaws filled with large, acuminate, irregularly (crookedly?) set teeth pointing outward and forward instead of backward as one would expect in a fish-catcher (Fig. 3). There were multitudes of fishes in the Upper Jurassic seas, and these Rhamphorhynchus must have taken on the wing. But it is somewhat difficult to understand how in full flight he could catch and hold his slippery, scaly prey with these forwardly pointing teeth. Then when he had caught a fish, how could he, even by elevating his head, have got it started down his throat against the opposition of these wrong-way-pointing teeth? The paleontologists give no answer to this question. He presumably ate fishes, but

From Barnum Brown by courtesy of Sinclair Refining Company

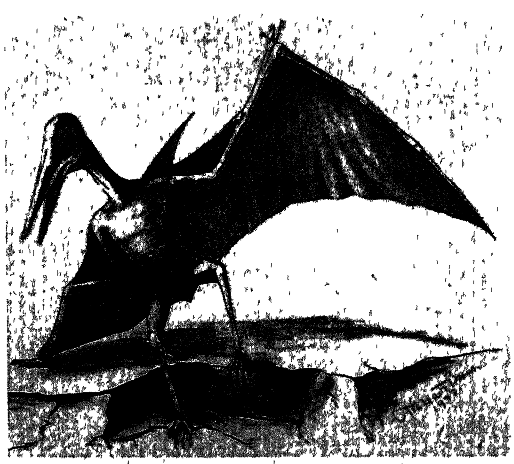
FIG. 4. RHAMPHORHYNCHUS IN FULL FLIGHT—SEEN FROM BELOW
THE LONG, NARROW WINGS ARE BOOMED OUT BY THE LIMBS AND THE PRODIGIOUSLY ELONGATED FIFTH FINGER OF EACH HAND. THE SPATULA AT THE END OF THE TAIL PROBABLY SERVED AS A HORIZONTAL RUDDER.

surely no fish-eater ever had teeth so ill adapted for catching or swallowing fish.

Furthermore, when this strange little beast came to make a landing, he probably did not light on the ground because his feet were weak and small. Since his long tail would be an encumbrance on the ground, he probably lighted on a tree trunk to which he could cling with the clawed toes of all four feet (Fig. 1). Up its rough bark this small pterosaur could climb until he reached a branch (Fig. 2) from which he could launch forth in flight. In Figure 1 the flying wing-finger is portrayed in oblique dorsal view, and in Figure 4 he is again portrayed in full flight, but from the ventral aspect.

The drawings showing the structures and activities of this and other flying dragons are of course restorations based on the bony framework of the beasts, but clothed by the imagination of the artist, who was guided, however, by the critical eye and judgment of the scientific man. The artist of Figure 4 was supervised by Barnum Brown, to whom I am indebted for this and other illustrations and for many essential facts about the three wing-fingers studied herein. For further information the reader should consult Brown's "Flying Reptiles" in *Natural History,* Vol. 52, pp. 104–111, 1943.

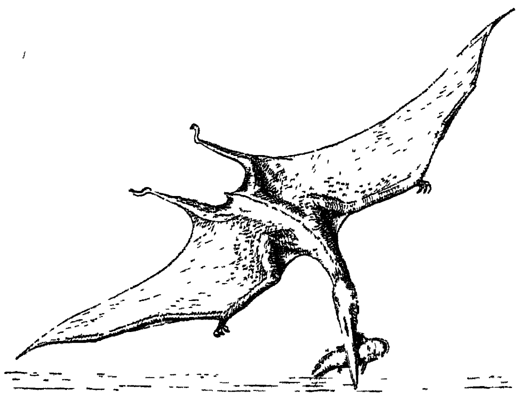
Pterodactylus (ter-o-dak-till-us), literally "wing-finger," was a very short-tailed, but long-necked, flying dragon. It was larger



After Barnum Brown, 1943

FIG. 5. PTERODACTYLUS ALIGHTING

SMALL, CONICAL, UPRIGHT TEETH ARE CONCENTRATED IN THE FRONT PART OF EACH JAW OF THIS WING-FINGER.



After Abel, 1919

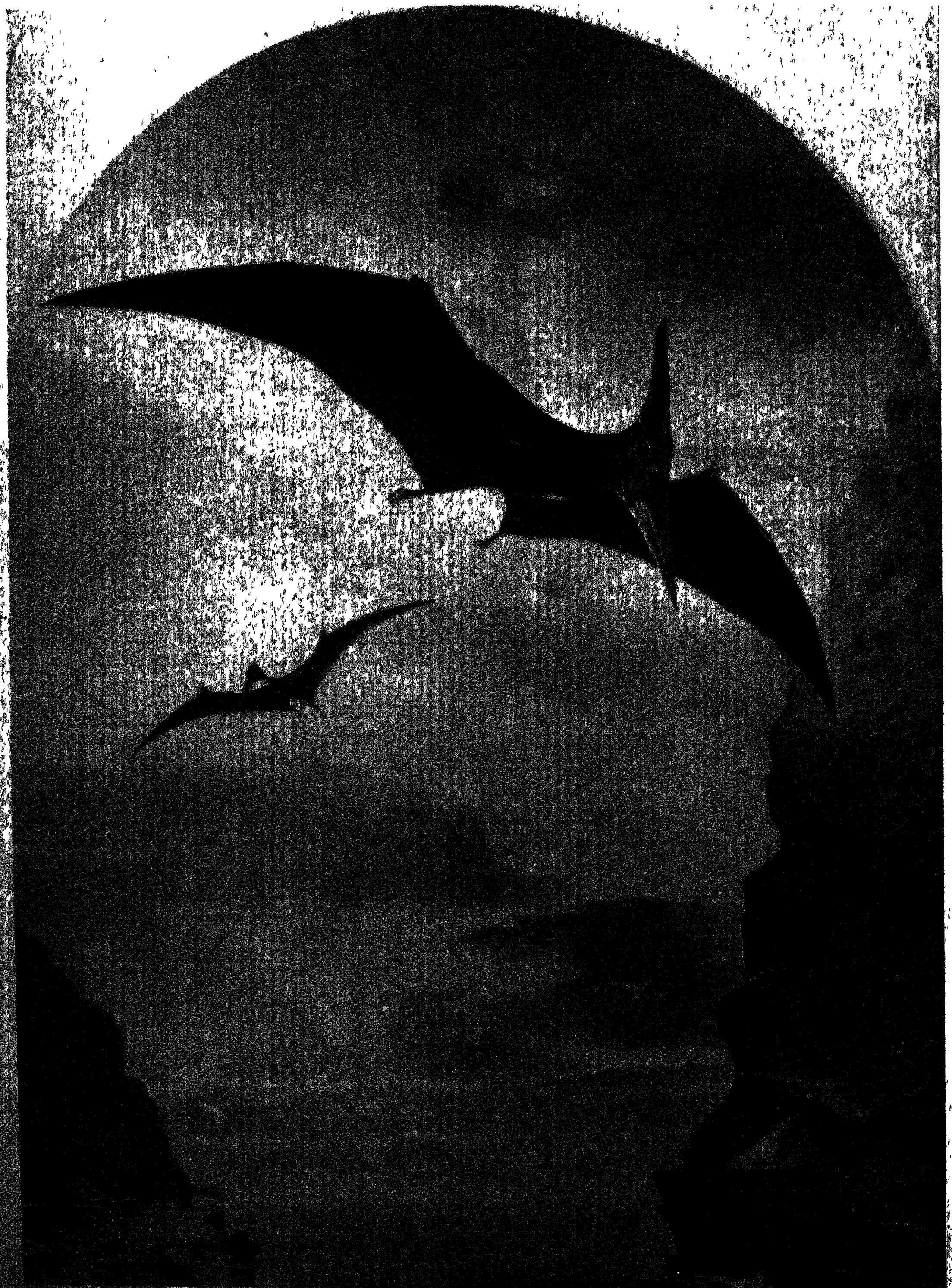
FIG. 6. PTERODACTYLUS FEEDING

SWOOPING DOWN ON WIDESPREAD WINGS, THIS FLYING DRAGON PICKED HIS FISH FROM THE WATER SURFACE.

and, as restored by the artist under supervision of Barnum Brown, more grotesque—in short far more weird in appearance (Fig. 5) than Rhamphorhynchus. Some species attained the size of an eagle and had longer limbs than the Crooked Beak. The wings of Pterodactylus were larger and heavier, and his small teeth, concentrated near the tip of each jaw, were conical and stood upright. They were much better adapted for catching fishes than those of the flying lizard just described.

Pterodactylus probably caught and ate more fishes than his distant cousin, Rhamphorhynchus. Of this activity, there is fortunately a splendid portrayal made under the supervision of one of the greatest authorities on the pterosaurs, Prof. Othenio Abel of the University of Vienna (Fig. 6). Swooping down on wide-extended wings, Pterodactylus picked up his surface-swimming prey as our present marine birds do.

Pteranodon (the toothless winged one) was the largest and, because of his extraordinary wing development, the best flyer of all the pterosaurs. His head was drawn out in front into long, dagger-shaped, toothless jaws and behind into a long thin supra-occipital crest. Brown thinks that the latter probably served as a rudder when this flying dragon dived headlong at its prey (Fig. 7). If it so functioned, it took the place of the spatulate rudder on the tail of Rhamphorhynchus.



After Barnum Brown, 1943

FIG. 7. PTERANODON, THE ORIGINAL DIVE BOMBER, IN FULL FLIGHT.
IT WAS THE LARGEST FLYING ANIMAL OF ALL TIME, ACCORDING TO PALEONTOLOGISTS. FROM THE FRANK BOYDEN SMITH MURAL ("WINDOW TO THE PAST") IN THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK.

After Barnum Brown, 1943

FIG. 8. THE SKELETON OF PTERANODON SHOWN IN VENTRAL ASPECT

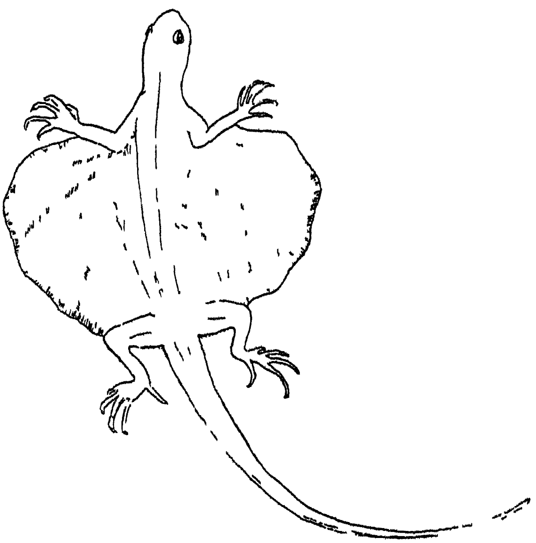
THE SKULL IS PRODUCED IN FRONT INTO LONG TOOTHLESS JAWS AND BEHIND INTO A LONG BONY CREST. THE SKELETON IS FUSED TO FORM A STRONG SUPPORT FOR THE WINGS. IN AN 8 FOOT-LONG SPECIMEN THE WINGSPREAD WAS 20 FEET, BUT THE HOLLOW BONES CAUSED IT TO WEIGH ONLY ABOUT 25 POUNDS.

The most perfect skeletons have been found in the Niobrara Cretaceous deposits of Kansas. The anterior limbs, and especially the "little fingers," are enormously elongated, and the wingspread of some 8-foot specimens was 20 or more feet. Despite the great wingspread, these light-boned animals weighed surprisingly little, probably not more than 25 pounds for a 20-foot specimen. Compare it with an albatross having an 11-foot spread and a weight of about 17 pounds. Brown thus characterizes the strongly knit skeleton: "A rigid framework of fused backbones, shoulder girdle, and breastbone furnished support for the enormous wings and for the attachment of muscles necessary to hold them in position, an arrangement unparalleled for strength among other animals." This highly coordinated bony framework is admirably portrayed in Figure 8, in which, however, the breast bone is not shown, since it has been removed so that the fused wing-bearing bones may be seen.

The paleontologists have long been puzzled over the food of the toothless Pteranodon, but they conjectured that it must have been fishes taken on the wing. This conjecture has recently been proven correct by the preparation here in the American Museum of the lower jaw of a specimen. In the pelican-like throat-pouch between the bones of the lower jaw were found the vertebrae of two kinds of fishes—the remains of the last supper of this particular flying dragon. For taking fishes his toothless jaws were no more ineffective than are those of a tern or gull. What an awesome sight it would have been, could one have seen a flock of these Pteranodons—the largest animals that have ever flown, the original dive bombers—swoop down on twenty-foot wings (Fig. 7) over a school of fishes in the Cretaceous seas of the Kansas of the Mesozoic era. Since they were extremely highly specialized, the Pteranodons became extinct as the Mesozoic closed.

Before leaving the flying dragons, it will be interesting to quote Sir Richard Owen: ". . . the flying reptile with outstretched pinions must have appeared like the soaring Roc of Arabian romance, but with the features of leathern wings with crooked claws superinduced, and gaping mouth with threatening teeth."

The extinct pterosaurs were the only reptiles that have ever really flown. However, among present-day animals of this group are some that are called flyers. The best example is the so-called "flying dragon," *Draco volans,* of the East Indies and southeastern Asia (Fig. 9). It has an umbrella-like membrane on each side from front to hind limb, each being partially free. These membranes are distended partly by the limbs but mainly by the movable ribs. They act simply as the wings of a glider and enable this lizard to glide or volplane from one limb of a tree to another, to another tree, or to the ground. But Draco cannot soar as did the pterosaurs nor flap its wings as the flying lizards may have done. Among mammals,



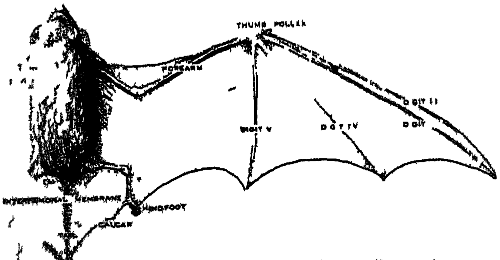
From H. G. Seeley, 1901

FIG. 9. THE FLYING DRAGON

THE "WINGS" OF *Draco volans*, FOR GLIDING ONLY, ARE SUPPORTED BY LIMBS AND BY MOVABLE RIBS.

the well-known flying squirrel has a similar membrane, unsupported by ribs, with which it also glides.

The thoughtful reader has already contrasted the pterosaurs with the only mammals that have ever really attained the power of flight—the Bats or Chiroptera (hand-winged ones). Every one knows that the bat has on the side a membrane extending from the front limb backward to, and embracing, the hind limb and at the short tail coalescing with the membrane from the other side (Fig. 10). But the pterosaur had all the digits of the forelimb free save the last (the little finger), which, acting as a boom, stretched the wing membrane taut for flight; the bat has only the thumb free, while the second and third fingers are tied fast to the wing. The four fingers act like the ribs of an umbrella to distend the membrane. To aid in this distension is the hind limb with the elongated great toe fast to the edge of the hinder part of the wing, the other toes being free. The tail also plays its part in this distension (Fig. 10). In the pterosaur the hind limb did its share of stretching the wing, while even in the tailed forms the tail played only a little part. With these shorter but stronger wings bats can both beat the air and soar, whereas the pterosaur was practically confined to soaring.



After Goodwin, 1935

FIG. 10. A BAT AND ITS WING

THE THUMB ONLY IS FREE; THE FINGERS BOOM OUT THE WING, ACTING LIKE THE RIBS OF AN UMBRELLA.

But the chiropterans are not direct descendants and close relatives of the pterosaurs. Bats are mammals and are far removed in time and structure from the reptiles. They have fragile bodies and wings, and these and their manner of life make their fossilization a matter of great difficulty. Their fossil remains are very rare. Consequently it is not known when they first appeared, but quite surely not in the Mesozoic. Their earliest remains have been found in the Eocene, the opening period of the Age of Mammals. But it should be noted that these fossils were "perfectly good" bats.

Whether these early winged mammals were fishers like the pterosaurs cannot be said, but it is probable that they were not. However, as I have shown in two articles, there are scattered around the world today some bats that are fish-catchers and fish-eaters. Thus *Pizonyx* in the Gulf of California is a fish-eater. So also in India and Burma certain false vampire bats (genus *Megaderma*) eat fishes. But the best known fish-catching bat is *Noctilio leporinus*, the rabbit-nosed bat of the Caribbean region. From time to time numbers of these bats have been seen fishing around Monos Island off the northwest coast of Trindad. Specimens taken at Monos and in Surinam have been found to have their stomachs crammed with fish remains. An article on this fish-catcher is in press.

The Odontornithes or Toothed Birds of the Mesozoic Era

Of all fossil remains, those of birds are among the rarest, and accordingly they are among the most highly prized. And this is

After Lucas, 1901

FIG. 11. *HESPERORNIS REGALIS*, THE GREAT WESTERN DIVER, IN ACTION
THIS HUGE BIRD, SIX FEET LONG, WAS THE GREATEST SWIMMER AND DIVER THE WORLD OF BIRDS HAS EVER HAD.

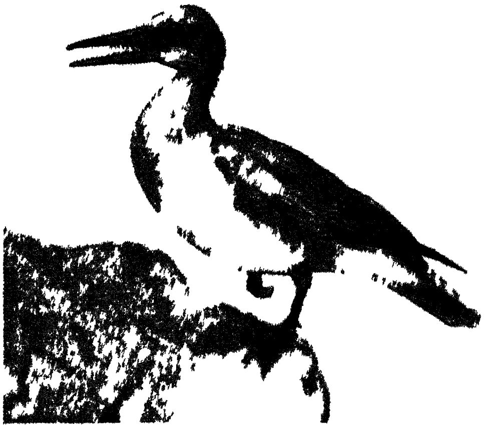
particularly true of the Odontornithes, the toothed birds. All of us have used the phrase "as scarce as hens' teeth" to emphasize the fact that the thing referred to simply does not exist. Yet in the upper Jurassic and middle Cretaceous deposits are found remains of birds with toothed jaws. Two of these birds flew with bird-feathered wings and the third was a wingless diver.

The earliest of these was Archaeopteryx, ancient winged one, or ancient flyer of the Upper Jurassic. It was feathered and flew with feathered wings but these feathers only thinly hid its reptilian characters; it was about equally lizard and bird. It was a forest dweller, and since it did not catch fishes, it may be passed by with these few brief words. The other Odontornithes were true aquatic birds and fish-catchers, which came on the scene thousands of years after Archaeopteryx, the lizard bird.

For all their equipment of teeth, these Odontornithes were true birds. Externally they had the form of birds and were covered with feathers; rudimentary perhaps but still feathers. One, though flightless, had some hollow bones and the rudiments of wings; the other, with a highly pneumaticized skeleton and well-developed wings, was an excellent flyer. In their fossilized skeletons are some reptilian characters, but their bony framework is overwhelmingly bird; they were birds even if they did have teeth.

They were discovered by the eminent paleontologist, O. C. Marsh of Yale University, in 1870–1872, in the Middle Cretaceous beds of western Kansas and were described by him in a publication entitled *Odontornithes: Monograph on the Extinct Toothed Birds of North America*, Washington, 201 pp. 1880. In those middle geologic days, what is now the Great Plains region was a shallow sea which extended from the Rocky Mountains quite 500 miles to the east, with unknown northern and southern limits. In this sea were a great variety and abundance of fishes, and here the toothed feathered fish-eaters likewise flourished.

The two forms to be studied were birds, but were the descendants of rapacious rep-



After Knipe, 1905

FIG. 12. *ICHTHYORNIS VICTOR*

THE LAST OF THE TOOTHED BIRDS, THIS FISH-BIRD, ABOUT THE SIZE OF A PIGEON, WAS A STRONG FLYER.

tilian flesh-eaters. They possessed not a few reptilian characters but the most obvious was their sharp-pointed, conical, backwardly hooked teeth composed of dentine covered with smooth, shining enamel—teeth eminently reptilian. Now our present-day birds have bony jawbones covered with horny sheaths. These sheaths are sometimes jagged or serrate but never toothed. The Odontornithes lacked these horny sheaths and had their teeth implanted in the jawbones. The two toothed birds being studied were contemporaries, but very different in certain structures and in manner of life. However, they had in common long spearlike jaws beset with recurved teeth—almost perfect instruments for the capture, retention, and ingestion of fishes.

Hesperornis regalis is the first to be considered. In 1871 O. C. Marsh was the fortunate discoverer, in the Niobrara deposits of western Kansas, of an almost complete skeleton of the "Royal Western Bird." And such indeed it was, for it measured nearly six feet from tip of beak to end of toes. However, it was flightless, having a flat (nonkeeled) breast bone and only the remnant of the upper wing bone (humerus) covered over by the skin and possibly by muscles. Even lacking wings it was still completely aquatic, since its powerful legs and marvellously developed swimming feet admirably fitted it for such a life (Fig. 11). Like the present-day loon it probably spent little time ashore save for nest-building and breeding.

Also in keeping with its flightless aquatic life was its complement of teeth, the lower jaw being toothed throughout and the hinder two-fifths of the upper jaw likewise so armed. These teeth had large bases and were set in a continuous groove in each jaw. These jaws with their conical, sharp-pointed, and backwardly hooked teeth were admirably adapted for catching and holding active, scale-clad, slippery fishes. The teeth were plainly reptilian, but on the other hand, from a fossilized impression of the skin of the upper leg, Hesperornis is thought to have been completely covered with smooth, soft, hairlike feathers (Fig. 11) similar to those found on the present-day flightless, but land-dwelling, Apteryx of New Zealand.

Everything about Hesperornis attests that it was the largest and most powerful swimming and diving bird that has ever lived. Lacking even rudimentary wings, but with the long-beaked head set at the top of a long flexible neck, its jaws beset with sharp hooked teeth, and its long and powerful legs ending in huge swimming feet, it was a fish-catcher of the first rank among diving birds past or present (Fig. 11).

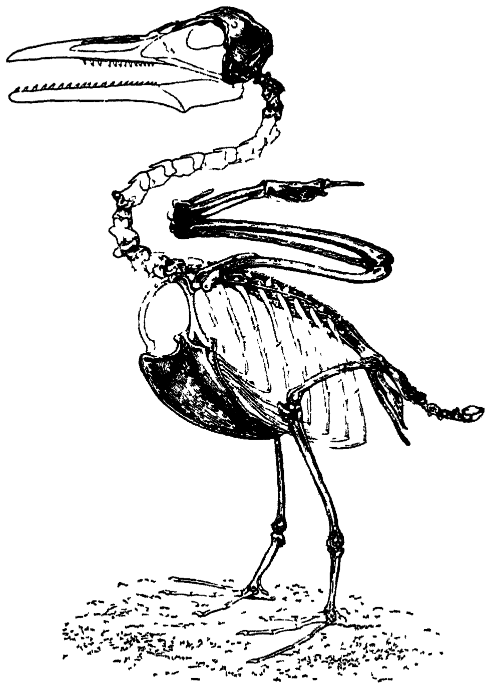
Ichthyornis victor, the other toothed bird, was also discovered by Marsh and in the same Cretaceous deposits in Kansas. Only one restoration of the bird as it looked in the flesh has ever been made, so far as I know. Seen in Figure 12, it shows a small, well-built, pigeon-like bird. It had a rather long neck ending in a large head and a long bill beset with strong teeth. In marked contrast to the mouth and forwardly pointing teeth of the flying lizard, Rhamphorhynchus, the jaws and backwardly hooked teeth of the toothed bird, Ichthyornis, surely constituted a far more efficient fish trap. The legs and feet are small in comparison with those of Hesperornis, but also in marked contrast are its long powerful wings. So much for its general external appearance.

But to see how well this flying fisherman

was equipped to take fishes at the surface of the water, the skeletal structure must be studied. No complete skeleton has ever been found, but Marsh has portrayed a restoration with the missing bones in outline (Fig. 13). From this it is seen how weak was the leg development, and in contrast how powerful were the wings. Then note the relatively huge, plowshare-like sternum for the attachment of the great flying muscles. Long, strong wing bones, big keeled sternum, and skeleton highly pneumaticized throughout, all proclaim Ichthyornis to have been a strong flyer—in marked contrast to the subaquatic manner of life of the Great Diver.

These avian characters are very apparent and tend to obscure the less apparent reptilian ones; nevertheless, these are present in many parts of the skeleton. The arrangement of the teeth in both jaws duplicated that of Hesperornis. These reptilian teeth were smaller, were sharp-pointed and strongly hooked toward the gullet. Unlike the teeth of Hesperornis, each tooth was set in a distinct socket. Another skeletal character in which Ichthyornis especially differed from the Great Diver and from all other birds is found in the vertebrae. Marsh (p. 119) states that " . . their biconcave vertebrae separate them widely from all birds recent and extinct, and point back unmistakably to a very lowly ancestry, even below the reptiles." And later he more explicitly says (p. 179) of these biconcave or fishlike vertebrae: "This form is seen in a few recent and in many extinct Reptiles, and in the Amphibians; but it is especially characteristic of Fishes, from which it was undoubtedly inherited by the superior groups. This character alone indicates great antiquity for the class of birds"—and especially for that one fittingly named Ichthyornis, (*ichthys,* fish; *ornis,* bird).

Ichthyornis was distinctly an aquatic bird, seeking its piscine prey in the warm Mesozoic seas. On this point Marsh gives evidence that "Its food was probably fishes, as their remains are found in great abundance mingled with those of Ichthyornis." Since its bones are found in the same Cretaceous deposits with those of the toothless Pteranodon, Ichthyornis must have competed with the latter for the fishes in the waters above which they both flew.



After Marsh, 1880

FIG. 13. SKELETON OF ICHTHYORNIS
NOTABLE ARE THE WEAK LEGS, THE POWERFUL WINGS, THE HUGE KEELED STERNUM, AND THE TOOTHED JAWS.

With the passing of the Mesozoic and the advent of the Cenozoic, or era of present-day life, the flying dragons and the toothed birds pass from the scene. Their successors were the ancestors of the birds of our times. And so we return to the gulls, terns, cormorants, and pelicans of our shores and of the waters around the *Bird Islands of Peru.*

SCIENCE WORKS WITH THE ARMED FORCES*

By REAR ADMIRAL J. A. FURER

When Dr. Jewett invited me to make a few remarks at this meeting, he said that I might talk on any subject that would help the scientist to see the point of view of the military man, and vice versa. So I am going to discuss the human relationships between scientists on the one hand and professional Army and Navy officers on the other. In my job as the Navy's Coordinator of Research and Development, I find that I spend more time coordinating human beings than I do in coordinating research and development. And I must confess that there seem to be times when the tables are turned and other human beings begin to coordinate me.

Early in my present assignment I discovered that the scientist and the military man have a common denominator. The common denominator is intellectual honesty. I have been impressed also with the fact that the world of science is not so impersonal and far removed from the common touch as is often supposed. I have found that scientists and professional military men alike are motivated by the same basic instincts and ideals—by pride in accomplishment, by desire for recognition for a job well done, by a passion for service, and by a deep sense of responsibility. And—a fact too seldom appreciated—I found that scientists are generally intensely practical people. Once they are given the military considerations involved, they can drive forward to a common-sense solution of a problem with a directness that comes as a surprise to those who think of scientists as living on a plane beyond the everyday world.

You will note that I have emphasized *professional* military men. The vast majority of officers in time of war are not professional Army and Navy officers. The reserve officers, for example, who deal with scientific matters are mostly scientists themselves, and they are a fine lot. It is the professional officer—the officer who, because of his training and experience *must* fill the higher position of responsibility—who needs most to see eye to eye with the scientist. In other words, it is the "Brass Hat" versus the "Great Brain" bogey which pops up to plague us from time to time.

It is perhaps only natural that "brass hattism" easily becomes a term of opprobrium in the public mind whenever anything goes wrong. Gold braid on the cap visor becomes the mark of a closed mind and a skull that requires trepanning to inject a simple idea. As a matter of fact, a lifetime of experience and the wartime responsibilities that go with brass hats usually make the wearer a pretty sound individual. I know of very few cases in which scientists and brass hats have not acquired considerable respect for each other's abilities—often to the astonishment of both parties!

In the mobilization of science for war, I am particularly proud of our mutual achievements in working out the human problem. It is not always easy to resolve the different points of view of the scientist and the military officer. In many respects our backgrounds are very dissimilar. In normal times the scientist looks upon the world as a friendly world. He likes to take all mankind into his confidence as soon as he makes a discovery. He wants his inventions and discoveries put to prompt use. He has a natural human desire to receive credit from his profession and from the public for the fruits of his labors. By contrast, the professional Army and Navy officer must think of the world as a potentially hostile world. It is his job to plan for the defense of his country, even in times of apparent peace. He cannot take the world into his confidence because one of the fundamental precepts of military science is to withhold from the enemy as long as possible all information about plans, weapons, and resources.

One of the unheralded victories of this war is the satisfactory manner in which these divergent points of view have been resolved. Today, the war has fused the scientific and the military mind in the common mold of

* An address before a closed meeting of the National Academy of Sciences in Washington, D. C., April 24, 1944.

public service. The scientist has been wise and patient in not clamoring for immediate credit for his contribution to the war effort. Publication of certain scientific papers has been cheerfully suspended for the duration. In the laboratory and in the field the scientist has worked tirelessly and without recognition, realizing that such recognition must, of necessity, be deferred until the cessation of hostilities. He has deferred to the necessities of what is commonly called "red tape," and he has done this despite the fact that his whole individualistic existence cries out against the formalized, channelized procedure which the Army and Navy tell him is necessary in dealing with so complicated a problem as modern warfare.

In bringing together the scientist and the military man, we of the military believe that we, too, have contributed materially to the good will and understanding that have been established. We, too, have made concessions for the common cause. There are few regular Army and Navy officers who pretend to be scientists, just as there are few scientists who pretend to be experts in applying scientific thinking to the making of war. We of the Navy have made every effort to remember our own shortcomings and to enlist the aid of the scientist in making up our deficiencies. It can also be fairly said that we have made every effort to eliminate red tape for your convenience. In the Navy I have constantly striven to get our officers to explain to the scientist why we do things as we do them, to overlook the petty irritations that arise in joint undertakings, and to forget personalities. Our prime responsibility is to win the war, and our goal is to enlist in this effort every ounce of assistance that we can summon from the civilian world of science.

Many of your fraternity have been taken into our full confidence on the highest levels. Dr. Bush, as Chairman of the Joint New Weapons Committee, is at an unprecedentedly high military level for a scientist. The views of eminent scientists in the National Defense Research Committee are continually sought and are respected. A great many scientists have traveled extensively in the theaters of war. Through the recently established Office of Field Service, scientists are beginning to appear wherever our forces are engaged.

If I were to take a poll of this audience to determine your chief problems in dealing with the military, I believe the answer would be "red tape" and "security," in that order. Now "red tape" is something that I have no desire to defend if the phrase is employed in the uncomplimentary sense in which it is generally used. But I will undertake to defend it if defined in the sense that I would define it—namely, as *orderly procedure.* We all like to dispense with procedure and to arrive at immediate decisions. We like to cut out the "middleman" and to shorten the chain of command to get things done. In other words, we like to take short cuts. There are times when short cuts are good and there are other times when they are not. If you are late catching the bus in the morning and take a short cut across your neighbor's lawn, he will not object if it happens once or twice. But if one hundred other people began taking short cuts across his lawn, that would be different. I suspect he would set up signs and try to channelize the traffic around his lawn. Now in organizations as large as the Army and Navy, it is absolutely necessary to set up procedures to direct the traffic and to fix authority and responsibility. These procedures are not needed perhaps in your laboratories, or, for example, in a small business establishment. But the Navy is no longer small business. Orderly procedure is necessary to avert traffic jams. And the need for orderly procedure increases arithmetically, if not geometrically, as the size of the undertaking increases.

You may think my remarks are purely academic. But let me cite an incident where failure to follow orderly procedure came near to causing trouble. A few months ago, I arranged for a small group of scientists and an officer from my staff to visit a unit of the fleet to talk over some problems. The Admiral, his staff, and the scientists quickly found a number of problems that merited research attention. At this point the next step should have been a letter from the Admiral to the cognizant Bureau, putting the wheels in motion. But instead, negotiations were started directly between the Admiral and the scientists to work out these problems without reference to the Bureaus concerned. I believe that both the Admiral and the scien-

tists were quite unaware of the importance of getting the ultimately responsible bureau people into the picture from the beginning. As soon as the chairman of the appropriate NDRC committee and I became aware of the situation, we got the matter straightened out before it had done any more damage than to upset a few of the most competent officers I know in the Navy. It was not merely a matter of feelings. The people in the Bureaus were ultimately responsible for the work and thus were placed in the untenable position of having to accept responsibility without being apprised of the undertaking, and, what is more important, the scientists might have gone along on the work without benefit of the experience of the Bureaus.

Do not get the idea that I or most Naval officers make a fetish of following the Mosaic law. I myself have frequently lifted projects out of the routine so as to shorten the chain of command in order to get a job started more quickly. This cannot be done in all cases and, if attempted, must always be done with judgment and discrimination; otherwise there is no gain.

Therefore, if I do say a kind word for "red tape," I do so only out of the depth of my long experience. Someone has to look out for the best interests of the whole fleet, and that is all that the "Brass Hats" are trying to do in stressing orderly procedure.

As for the other most audible complaint—the handling of security, we of the Army and Navy appreciate the cooperation you are giving us in trying to keep our plans and devices away from the enemy as long as possible. Scientists are playing the game of security with commendable forebearance and sportsmanship. But before you complain about the stringency of some of the rules, let me hasten to confess that I myself do not think that the rules are always sensibly applied. I am constantly battling to get the rules changed where necessary. While we all agree that we should prevent helpful information from reaching the enemy, as I see it this policy is sometimes carried to the point where we keep much needed information away from our own people. I think it is particularly shortsighted to restrict too closely the number of scientists who are permitted to know about important research projects. My platform is that anyone who can contribute in wartime to the more *speedy* solution of any of our problems should be brought into the picture. On the other hand, it goes without saying that there is no justification for disclosing classified information merely to satisfy someone's curiosity, no matter how exalted that person's position may be. Of course, no matter how discreet those may be who are in on a secret, the probability of a leak increases geometrically with the number of people who know about it. The number is, however, at the very most not large during the research and development stage as compared with the number who must know as soon as the device is placed in service.

Almost any reasonably sound proposal for a new device can be realized if enough talent and enough money are provided. There is no such thing as permanent secrecy of ideas, or even very much lag in the flowering of the same ideas in the brains of the enemy. I plow through vast heaps of intelligence reports and am pretty well convinced that the enemy is trying to do all—or most all—of the things we are, and is certainly thinking along virtually the same lines. True security lies in speed of accomplishment. It is the only way we can keep ahead of the enemy in this complex technical war of measure and countermeasure. Together we examine the problem, you furnish us the scientific alternative solutions, we both weigh the corollary problems of manpower, cost, time, and production; and, once the decision is made, our real security lies in how soon the fruits of the job will bring grief to our enemies.

The following lines from Kipling's ballad *The "Mary Gloster"* often strike me as particularly appropriate to the technological warfare being waged between American scientists and the enemy, especially the Japs:

> They copied all they could follow,
> But they couldn't copy my mind,
> And I left 'em sweating and stealing
> A year and a half behind.

It is that jump on the enemy that counts these days, and only with the unselfish devotion of scientists in laboratories all over the country can we maintain and widen our lead.

ARE WE FACING SEVEN LEAN YEARS?

By CARL F. TAEUSCH

DURING the past seven years, agricultural production in this country has been nothing short of bounteous. From the standpoint of physical production, these have been fat years; certainly with respect to such major crops as corn, cotton, and wheat, and probably also for other crops and livestock products. What is the likelihood for the future?

"Man lives not by bread alone," said Robert Louis Stevenson; "he also lives by catch phrases." And the biblical story of Joseph has been ringing in our ears long enough to provide a fertile field for the warning that, now that the seven fat years have passed, the next seven years may not be so plenteous. The warning is supported by the reminder that the weather, one of the most potent single factors in farm production, has been unusually favorable in the recent past, and that we may soon face the adverse trends of the rainfall cycle. In a sense, this warning may also reflect man's pessimistic proclivity to say, "This good cannot keep on indefinitely." Hearing these ominous notes, what can we conclude as regards the future?

The hazards of prophecy are at their maximum when agricultural production is being forecast. This is the case, not only because of the indeterminable weather factor, but also because of the bases on which the forecasts are so often predicated. Like the trite inquiry, "Will the sun rise tomorrow?," too many affirmative answers are based on the proposition, "Because it always has." And the fact that the two major fallacies in this answer were pointed out long ago, does not seem to disturb this kind of prophet. We do not, as a matter of strictly observed fact, know that it is true that "the sun has always risen"—some people never have seen the sun rise!—and even if it were true, that does not help us with respect to tomorrow's sun. The fact that crop statistics have been available in this country only since the War between the States and are not too reliable in the earlier part of the record limits us in any attempts to be even as general in our observations as we are in regard to past appearances of the sun. And whether next year's crops will follow the patterns of the past is not only questioned by such cyclical views as that of the seven fat and seven lean years, but the prophecy also often stumbles against the hard fact of an extremely exceptional year or the beginning of a reversal of past trends.

What can we say, therefore, even in general, as to the prospects for the immediate years ahead? Is there a method which is better than that of the observer on a hill who has seen the sun rise a number of mornings in succession and who may have his prophecy confirmed tomorrow? Can we approach the matter more as the astronomer might, without even observing the rising of the sun, by discovering the various factors at work in a complex system that is not subject to daily or annual hazards?

We do need to look at the past record. And, although we shall confine ourselves to the production trends of three of our major crops—corn, cotton, and wheat—we can here point out certain other factors in the agricultural production situation. Agricultural production in recent years has been characterized by a shift from the earlier preponderance of field crops as the major source of farm income to the present preponderance of livestock and livestock products as the major direct source. Therefore, the relatively declining importance of field crops as a direct source of gross farm income would make recent increases in production and in absolute income value all the more significant; and they are as feed the indirect source of much of the absolute and relative increases in farm income from livestock production. Furthermore, even among the field crops, these three staple commodities have recently been supplemented by other farm products, sometimes at their expense. Thus, the Agricultural Adjustment program encouraged the diversion of crop acreage to increased pasture land, and the outbreak of

the war and the cutting off of our southwestern Pacific sources of vegetable oils witnessed a tremendous diversion of staple-crop acreage to the production of soybeans, peanuts, and similar crops. The resulting decline in corn, cotton, and wheat acreage makes all the more striking the phenomenon of the past seven years, in which the production of these staple crops was not only maintained but even increased.

Thus, in spite of a reduction of acreage in corn during the past seven years, amounting to some 9 million acres, or 9 per cent from the previous 38-year average, the total annual number of bushels of corn actually produced each year from 1937 to 1943 has been among the greatest in our history, averaging almost 7 per cent greater than the previous 38-year average. Cotton acreage, during the past seven years, declined relatively even more than did corn acreage: over 9 million acres, a decline of almost 27 per cent from the previous 34-year average. And yet total annual cotton production has recently averaged slightly higher than it ever did prior to 1937. Wheat does not present such a clear-cut picture. The past seven years have shown an 18 per cent increase in average total annual production over the previous 40-year average, but total acreage has averaged 8 per cent higher than before 1937.

These production records are cited without referring to the need or market demands for the three commodities. However much "the law of supply and demand" may operate elsewhere, demand does not operate so simply in determining agricultural production. Not only is there a considerable lag in its effectiveness; but often the lack of demand expressed in a low price, has stimulated the farmer in some years prior to 1937 to increase his production in order to maintain his gross income. The last seven years, it must furthermore be remembered, did not include the two drought years, 1934 and 1936; but the figures for the preceding 34 to 40 years with which comparisons were made, included enough years to reduce appreciably the effects of these drought years on the average annual production figures. We may consider ourselves extremely fortunate that we had such abundant production recently; markets have been stimulated directly and indirectly by the war, and we are even using up the cotton and wheat surpluses that for a while seemed so menacing. But we are disassociating here any relationship between demand and production, and are centering our attention on production data only. Market and demand considerations, and weather conditions, however they may operate as causes, should not blur the brute fact that agricultural production, at least of corn, cotton, and wheat, has been characterized by abundance during the past seven years.

We ask, "Will this abundance continue in the immediate future, or are we facing a reversal of trend so that seven lean years are in the offing?" A frank answer would honestly have to take account of the possible vagaries of market conditions as well as of the weather; and it would have to be, "We don't know." We should not, however, allow any answers to go unchallenged which rely merely on folklore or on catch-phrases or loose analogies. And we may be able to formulate a probable answer on the basis of factors which underlie the whole production situation, factors of which the production figures are symptomatic. And some of those factors may be discovered by analyzing past records of acreage, production, and yields per acre to see what has determined our agricultural production.

Agricultural production in America has been determined largely by the number of acres in cultivation. It may seem to some to be obvious that corn production, for example, is a product of the yield per acre by the number of acres in corn, which it is; and that total production varies equally with, or proportionally to, both acreage and yield. But, strange as it may sound, this latter statement is not the case. In general, ever since the War between the States, changing production has been more nearly proportional to changes in acreage than to changes in yields. As the West was settled, and new corn land was opened up, the total national production of corn increased, and it increased pretty much in proportion to the increase in acreage. And this relationship between acreage and production was very

close, in view of the fact that national-average yields per acre remained almost constant, when averaged over 15 or more years, until fairly recently. It has been only comparatively recently, as the acreages of corn, cotton, and wheat have become stabilized or have declined, that one can see—as one would expect—an appreciable and increasingly close correlation between yields per acre and total production.

This phenomenon of practically constant yields, prior to 1937, is startling. It would evidence no appreciable effect of all the educational work of the colleges of agriculture and the federal and state departments of agriculture, at least in the direction of improved farm management which presumably would result in increasing yields per acre. The pre-1937 record of yields also stands out sharply in contrast with that of the past seven years, during which time this previous record of constant yields, over periods of that many or more successive years, has been broken for the first time since the War between the States. From 1867 to 1936 corn production averaged over successive periods of 15 or more years and for the total 70-year period almost exactly 26 bushels per acre. The more recent part of that 70-year record, namely 1899–36, averaged even slightly less than the earlier (1867–98) part of that period, showing that there was no pre-1937 trend toward increasing yields of corn per acre. For the past seven years, however, the national average yield of corn per acre has been slightly over 30 bushels. So also with cotton. Yields averaged around 180 pounds per acre from 1876 to 1936. From 1876 to 1902 they were slightly more; from 1903 to 1936 they were slightly less. During the past seven years, cotton yields have averaged almost 250 pounds per acre. Wheat averaged from 13 to 14 bushels per acre from 1866 to 1936, with little variation in the averages of successive periods of 13 to 18 years during that time. For the past seven years, wheat has averaged over 15 bushels per acre, with the more recent years showing even higher figures.

How can we account for this interesting phenomenon of constant yields of these three major commodities over so long a period prior to 1937? Acreage and total production were both increasing appreciably, but they were increasing proportionally to each other. True, as crop acreage was increasing, it was extending itself into the newer western areas and the result may have been that the richer and more productive or the drier and probably less productive areas neutralized any possible decreases or increases in crop yields in the older, eastern areas. But a study of yields in the older agricultural states shows the same phenomenon of relatively uniform yields throughout the total pre-1937 period. Weather conditions, especially favorable rainfall or drought, may have increased or decreased production and yields in particular years. But in general, the correlation between acreage and production, prior to 1937, was much higher (0.89 for corn, 0.93 for cotton, and 0.95 for wheat) than it was between yields and production (0.473 for corn, 0.407 for cotton, and 0.647 for wheat). However we may account for the phenomenon, the fact seems to be clear that, at least prior to 1937, the total national production of corn, cotton, and wheat, was much more nearly proportional to acreage than it was to yields per acre. During the past seven years, beginning with 1937, the reverse has been true: annual production totals of corn and cotton have been much more nearly proportional to yields per acre than to number of acres harvested, and the total annual production of wheat has been relatively more so.

Now, it is conceivable and highly probable that, with vast areas of cheap land available, farmers preferred to engage in what may be called extensive farming, rather than in the more expensive operations of intensive cultivation which might have produced higher yields. Higher yields, as such, are not necessarily synonymous with sound farm management. Land was cheaper than labor, and it could be expected that cultivated acreage would be extended westward rapidly as an expression of more intelligent management than one which would adopt the policy of more intensive operation in the older eastern areas. Furthermore, it is understandable why the Agricultural Adjustment program of the early 1930's adopted the methods it did: crop-production changes from year to

year had for a long time been closely proportional to annual changes in acreage; therefore any program of crop curtailment could be expected to be achieved best by a reduction in acreage. What actually happened—that suggested acreage curtailments were not fully effected, that two severe droughts curtailed production through declining yields as much as the program had contemplated effecting through reduced acreage, and that the more intensive cultivation of the reduced acreage may have neutralized in part the objective of the program—does not affect the main proposition, that yields had been a relatively constant factor in American agricultural production up to 1937, and that changes in total crop production, at least until 1937, had been pretty closely proportional to changes in the amount of acreage harvested.

What has happened during the past seven years, therefore, stands out all the more clearly by contrast with the preceding record. Increased or maintained total national production of corn, cotton, and wheat is not a new story in American agriculture. But it is something new that production has been increased over a period of several successive years without increasing acreage, or that it has been maintained with decreasing acreage. What has happened has been the startling increase in yields.

Corn, with a relatively constant national average yield of less than 26 bushels per acre for some 70 years prior to 1937, or for periods of 15 or more years during that time, has averaged over 30 bushels per acre during the past 7 years, and immediately following a 38-year average of less than 26 bushels per acre. In the last 7 successive years, the minimum average national yield has been 28 bushels per acre; in 1942 the yield was just under 35 bushels per acre. In 1943, the yield was 30 bushels per acre, a figure achieved by any annual yield only four times in the previous 70 years.

Cotton, with average annual yields previously ranging from 160 to 190 pounds per acre for periods of 13 years or more, and a national pre-1937 average of 180 pounds, has averaged 248 pounds per acre since 1936. This latter figure had never before been achieved in any single year, the highest previous yield having been 225 pounds; in only 12 years previously did cotton yields exceed 200 pounds per acre. In 1942, the yield was 275 pounds per acre; in 1943, 259 pounds.

Wheat yields during the latter part of the pre-1937 period showed a slight rise over the earlier part of that period—from around 13 bushels per acre to around 14. The past seven years have averaged 15.3 bushels per acre. In 1942, the yield was 18.65 bushels per acre; in 1943, it was 16 bushels.

It is generally agreed that favorable weather had much to do with these unusually high yields during the past seven years. Rainfall was abundant and generally came at the right time in the growing season. When it did not—last year too much rainfall in the spring retarded planting and rotted much seed in the ground—later warm weather overcame this handicap. Rainfall has been increasing since the drought years; we are still in the upswing of the rainfall cycle, and this fact provides the pessimists among the prophets with their strongest argument that lean years are looming ahead.

But other factors are also at work, and they are significant as regards future possibilities. Selection and use of better seed has worked for higher yields, especially since 1936 as regards corn and cotton. The extension of the use of hybrid corn has had nothing short of phenomenal results. Iowa has averaged over 50 bushels of corn per acre during the past seven years, a yield of 60 bushels having been reached in 1942. Illinois, Ohio, and Indiana averaged over 45 bushels per acre since 1936. Average national yields in the future are bound to reflect the extension of hybrid corn into the western and southern areas, where yields have been less than 20 bushels per acre and where hybrid corn has only tardily been introduced. Cotton yields in the bigger areas of Texas and Oklahoma rose above 175 pounds per acre during the past seven years, a large yield for that region. In the Mississippi Delta region, yields averaged well above 325 pounds per acre, Alabama and Georgia topped 230 pounds, and the Carolinas were well over 300 pounds to the acre.

These are unusually high yields for these respective areas, and they have been pretty well sustained during the past seven successive years. True, a high-yielding seed may not necessarily produce the better grades of cotton—we are actually facing an insufficient supply of the longer staples—but whatever the high total-production figures may signify, economically or otherwise, they have been increasingly the result of higher yields, and a part of this higher yield can be attributed to better seed. Uniform-staple communities have been increasing, and the securing of better grades of seed—aside from their high-yield virtues—is one of the important functions of such organizations. Where the higher-yielding seeds are adopted by such communities because they also provide uniform staples that are in relatively greater demand, the resulting production is of especial value. The wheat situation is not so clear, and the more modest increases in recent national average yields may be due solely to the weather. At least there is less evidence of the prevalent use of the higher-yielding varieties of seedwheat, although there has always been a demand for, and increasing use of, disease- and drought-resisting varieties, which contribute to increasing yields.

Better cultivation, increased mechanization, greater use of fertilizers, and other improved farm practices, including the use of adequate amounts of insecticide on cotton, have also contributed to the results of higher yields. The balancing of land values against labor costs may determine the relative swings to more or less intensive cultivation, but the completion of the settlement of our best lands has more recently weighted the scales heavily in the direction of better utilizing available land, especially by increasing yields. The soil-conservation practices begun in the early 1930's at that time salvaged our fast-wasting soil; now those soil-building practices are beginning to pay dividends by also contributing to higher yields. The "ever-normal granary" is not confined to stocks of food or fiber on hand; it also consists in providing a reservoir of well-conditioned soils. The diversion, to other crops and to pasture, of low-yielding corn, cotton, and wheat land has reduced considerably the acreage devoted to the three staple crops; while this may seem to achieve a result of higher yields by statistical methods,[1] it is indicative of better farm management. And the maintenance of, or even increase in, the total national production of corn, cotton, and wheat on the reduced acreage, makes the resulting total national production as well as the higher yields per acre all the more significant, in view of the fact that the additional crops and pasture produced on most of those diverted acres practically constitute a net increase in the nation's food supply.

The greater productivity of the past seven fat years thus comes to be seen as a result of many factors, which do not by any means resolve themselves merely to the vagaries of the weather. It is highly doubtful that there will be any cyclical swings in better seed selection or in other forms of better farm management that were learned and applied during the past decade. They are here to stay. Labor shortages and difficulties in securing farm machinery, fertilizer, and insecticides may temporarily check any proclivities toward further intensive cultivation, but these will not apply to the postwar period. Price and farm income trends may seriously interfere with the continued operation of the controllable production instruments which have recently resulted in higher yields, but they are also in part man-made and are therefore amenable to intelligent legislative policies and individual cost controls. In short, it seems as if we face the possibility of intelligently continuing the operation of many of the factors which have effected the phenomenally high yields of corn, cotton, and wheat during the past seven years, and therefore of providing an abundance of food and fiber for a war-ridden world. The weather may qualify the results,

[1] Abandoned acreage (acres planted but not harvested) may at first appear as even a more extreme case of the same potential fallacy. Although a part of the abandonment of planted acreage results from drought, floods, hail, etc., some of it also arises from the fact that the original planting of such acreages was due to poor judgment. In any case, the factor does not enter into our calculations; the figures here cited are based on harvested acreage.

but not to the extent of facing us with an inevitability of seven lean years.

Our dependence in past years on a vast and untouched domain for the greater part of our expanding production, has had to give way before the brute fact that that source ceased to exist. Recently, our reliance has shifted to methods of more intensive cultivation, in which the abundance of our farm crops has been obtained by increasing yields. Underlying this situation appears to be the fact that farm production, which formerly increased largely through the opening up of new land areas and which was largely subject to the vicissitudes of the weather, more recently has resulted from controllable factors involved in intelligent farm management. If increased or maintained total farm production is needed in the future to feed our own people adequately as well as for export, we need to increase either net acreage or yields to accomplish the purpose. Increased acreage on any considerable scale is out of the question; good farm management may even require the diversion of existing poor cropland to other purposes. Thus we are practically forced to rely on increased or maintained yields for producing the farm products which are to supply future needs. Inasmuch as increased production in the past was obtained largely through increased acreage, because land was cheaper than labor, we may now be faced with higher farm-labor costs, if we are to increase or maintain yields. But this problem can be met by increasing the efficiency of farm labor, a possibility which has been resorted to by industry and commerce, but which is merely on the threshold of being utilized in agriculture. From the standpoint of physical production, therefore ,aside from economic events and policies that may disturb the situation, there is every reason to believe that the past seven-year record of abundance can in large part be continued in the future by increasingly intelligent farming.

APPENDIX

Tables 1, 2, and 3 were compiled so as to show trends and interrelationships in acreage, production, and yields of corn, cotton, and wheat.

The periods were selected, first, by grouping five sets of approximately equal numbers of consecutive years, differing for each commodity, and beginning with the earliest available records. These periods were then checked for the relative homogeneity of their constituent years. This was done by shifting the terminal years of each period to the adjacent period; if the resulting arrangement increased the homogeneity of both periods, the process was repeated until the maximum of homogeneity of the annual figures within each of the five periods was achieved for each crop. The annual averages were then calculated for each period; and the percentages of these averages, with reference to the over-all annual average, were calculated.

This method brings out clearly the relative constancy of the average yields for the successive periods of time for each commodity, except for the more recent years. It also presents, when the percentages of acreage and production are compared, a rough basis for showing the close relationship of these two factors, again until the higher yields of the more recent years changed the situation.

The method of multiple correlations provides some substantiating evidence verifying these results, especially as regards the relationships over the longer periods of time. It does not, however, supplant the method of averages here employed, especially for the successive shorter time periods, because it does not disclose the differing bases—of average acreage, production, and yield for the respective periods—upon which rest the correlations shown in the following table.

VALUE OF r (CORRELATION COEFFICIENT)

Periods	Acreage: Production			Production: Yield		
	Corn	Cotton	Wheat	Corn	Cotton	Wheat
Over-all (68–78 yrs.)	0.877	0.871	0.942	0.530	0.424	0.667
Prior to 1937 (61–71 yrs.)	0.891	0.928	0.949	0.473	0.407	0.647
1937–43	0.519	0.980	0.274	0.888	0.785	0.546
Earlier part, pre-1937	0.922	0.936	0.937	0.463	0.715	0.689
Later part, pre-1937	0.423	0.746	0.796	0.956	0.689	0.605

TABLE 1. CORN (ANNUAL AVERAGES)

Period	No. of years	Acreage (millions)		Production (million bushels)		Yield (bushels per acre)	
1867–1943	77	84.039		2,205.79		26.195	
		Mill. acres	% of 1867–1943 aver.	Mill. bu.	% of 1867–1943 aver.	Bu. per acre	% of 1867–1943 aver.
1867–83	17	51.0	60.69	1,308	59.28	25.65	97.93
1884–98	15	79.4	94.48	2,079	94.24	26.14	99.79
1899–1915	17	97.4	115.95	2,628	119.15	26.98	103.01
1916–32	17	102.0	121.40	2,646	119.97	25.94	99.01
1933–43	11	92.9	110.58	2,434	110.33	26.29	100.37
1867–98	32	64.3	76.52	1,669	75.67	25.88	98.80
1899–1936	38	99.4	118.31	2,561	116.10	25.74	98.26
1937–43	7	90.7	107.94	2,731	123.82	30.10	114.91

TABLE 2. COTTON (ANNUAL AVERAGES)

Period	No. of years	Acreage (millions)		Production (million bales)		Yield (pounds per acre)	
1876–1943	68	27.31		10.6718		187.05	
		Mill. acres	% of 1876–1943 aver.	Mill. bales	% of 1876–1943 aver.	Lbs. per acre	% of 1876–1943 aver.
1876–88	13	16.0	58.63	5.965	55.90	171.6	91.74
1889–1902	14	22.9	83.75	9.052	84.83	189.0	101.05
1903–15	13	31.5	115.24	12.613	118.16	190.9	102.04
1916–29	14	36.8	134.91	12.672	118.74	163.4	87.37
1930–43	14	28.8	105.61	12.862	120.52	217.8	117.35
1876–1902	27	19.6	71.65	7.566	70.90	180.6	96.57
1903–36	34	34.0	124.44	12.679	118.81	172.8	92.39
1937–43	7	24.7	90.61	12.902	120.89	248.3	134.59

TABLE 3. WHEAT (ANNUAL AVERAGES)

Period	No. of years	Acreage (millions)		Production (million bushels)		Yield (bushels per acre)	
1866–1943	78	45.0		623.855		13.683	
		Mill. acres	% of 1866–1937 aver.	Mill. bu.	% of 1866–1937 aver.	Bu. per acre	% of 1866–1937 aver.
1866–78	13	23.8	52.78	296.9	47.59	12.45	90.56
1879–96	18	37.9	84.16	506.3	81.16	13.32	97.36
1897–1913	17	47.4	105.40	672.0	107.72	14.19	103.69
1914–29	16	58.7	130.54	827.6	132.66	14.09	103.00
1930–43	14	55.2	122.76	787.3	126.20	14.22	103.90
1866–96	31	32.0	71.00	418.5	67.08	12.96	94.68
1897–1936	40	52.9	117.64	739.6	118.56	13.97	102.06
1937–43	7	57.4	127.61	871.7	139.73	15.30	111.83

AN EMPIRICIST'S SYSTEM OF THE SCIENCES

By GUSTAV BERGMANN

A PHILOSOPHER who presents his views on the systematic interrelations between the sciences is often expected to begin by indicating, at least in broad strokes, the philosophical position upon which his views on science are based. If I were to follow this pattern, I would first have to answer such questions as these: What is modern empiricism? Is its ontology realistic or idealistic? Is its epistemology rationalistic like that of Descartes and Kant, or empiricistic in the sense of Berkeley and Hume? Is its position to the mind-body problem dualistic or monistic? And so on and so on. Clearly, no worthwhile exposition of this kind could be given, not even in the most sweeping terms, by way of introduction to a brief, nontechnical presentation. It is therefore rather fortunate that a contemporary empiricist can dispense with such a "philosophical" introduction so long as he restricts himself to some of those topics which it has become customary of late to discuss under the heading of the philosophy of science. For it is a result of the empiricist analysis of the epistemological problem that this analysis itself is quite irrelevant to the methodological understanding of science. In this respect modern empiricism finds itself in harmony with the intellectual temper of our age and its tendency to exalt science at the expense of philosophy. However, contemporary empiricists refrain from the extreme formulations of those who thought that nothing could be saved from the apparent wreckage of philosophy except mathematical logic and the philosophy or, as they prefer to call it, the methodological analysis of science. Philosophy or, to make one more verbal concession to the lovers of well-established words, metaphysics will never die. It is true, though, that under the impact of both social changes and scientific developments philosophy also changes its form. It seems thus safer to say that modern empiricism in its fight against the classical frame of reference has not so much succeeded in exterminating metaphysics once and for all, but rather that it has tried to supplant older and by now outworn ways of philosophical speculation by its own characteristic emphasis on mathematical logic and language analysis on the one hand and its own anti-ontological theory of knowledge on the other. In this attempt modern empiricism has been very successful indeed if one is to judge from the impact of its conceptions upon contemporary thought, both scientific and social. But lest all this sound overconfident, let me add that I, for one, am firmly convinced that modern or, as one also says, logical or scientific empiricism will in turn not escape the fate of all historical phenomena, the fate, that is, of being devoured by its own children.

Historically speaking, scientific empiricism can be traced back to three roots, one American, one British, and one Continental. The American root is pragmatism, as represented by such men as Peirce, Mead, James, and Dewey. The British group is that of the Cambridge analysts centered around G. E. Moore, who led the revolt against idealism in England, and Bertrand Russell. Among the Continental thinkers, finally, who were widely scattered over the geographical expanse of Europe, the best-known group is the so-called Vienna Circle, whose members are also spoken of as logical positivists. The most significant earlier figure in the European thought movement was probably the physicist-philosopher Ernst Mach who brought the anti-Kantian movement, which had been started by Helmholtz, to its first fruition. Relatively well known among scientists are also the French mathematician-philosopher, Henri Poincaré, and the Englishman, Karl Pearson, the author of the once-famous *Grammar of Science,* whose views show a rather close similarity to those of his contemporary, Ernst Mach.

But this is not a paper on the theory of knowledge or on the history of philosophical ideas. The main point here is that, in order to understand completely the logical and methodological structure of science, one does not need to delve below the level of common sense and ask such questions as: "What is

a physical object?"; "How can the investigating scientist be sure that there is anything at all outside his consciousness?" To say the same thing positively, in the philosophy of science we can take it for granted that we know the meaning of such statements as: "There are seventeen chairs in this room"; "The pointer of this instrument is at rest or has just moved to the scale point inscribed '5,'" and so on. In such a crude and sketchy formulation the phrase "knowing the meaning" may be considered as equivalent to the phrase "knowing how to verify." Statements as simple as those which have just been mentioned for the sake of illustration are, of course, verified by the scientist's direct observation of simple objects or, somewhat more accurately, of physical things and certain qualities of them which are open to immediate inspection, such as color and hardness, including certain equally simple relations on the qualitative level such as mutual position, motion, and temporal succession. Even these few remarks will suffice to indicate what one means when he says that the empiricist analysis of science starts from the level of common sense. Let us now consider some of the consequences of this apparently trivial assumption.

If all the scientist can verify are statements about physical things of the simple type indicated, and since we obviously shall not want to include into any science statements which are unverifiable, how then, is it possible to make scientific statements about such "non-things" as electrical currents, magnetic fields, gravitational forces, atoms, electrons, protons and, on the other end of the traditional system of the sciences, about human motives, thoughts, perceptions, and cultural phenomena in general, on the group as well as on the individual level? Looked at in this way our starting point, which appeared to recommend itself as mere common sense, seems to be highly restrictive, very one-sided indeed, or, at best, heavily biased in favor of the so-called physical sciences.

Before proceeding, I should like to call attention to the manner in which the traditional division between physical, biological, and behavior science is understood in this paper. The physical sciences just mentioned comprehend physics and chemistry; the behavior sciences are understood to cover such a wide range of relative complexity as, at the one end, the behavior of animals in a learning experiment and, at the other, the socio-psychological phenomena of man and his society, including the arts and belles-lettres. The biological sciences occupy the rest of the field, that is, an area which is conveniently visualized as intermediate between physical and behavior science. Whether any such division of the sciences is a hard and fast one, of basic methodological and, as some earlier philosophies maintained, even metaphysical significance, or whether it is merely a classificatory device within a unified structure, to be explained historically and justified only as a matter of expediency in view of the necessary division of labor among investigators, is one of the main questions every philosophy of science has to answer. Empiricists very vigorously assert the latter of these two alternatives and maintain what is called, ambiguously as shall be seen presently, the thesis of the "unity of science." This position even found expression in the title of one of their most representative publications, the *Encyclopedia of Unified Science*, a series of monographs published, since 1938, by The University of Chicago Press.

Methodological structure of the physical sciences. It seems advisable to restrict our problem for the moment and to leave the biological and behavior sciences out of consideration. In other words, I shall first speak about the methodological structure of the physical sciences. Since these sciences are not only practically most successful but also theoretically and historically the most mature and advanced, it stands to reason that from their study we shall obtain some valuable hints concerning the task and nature of science in general. With respect to the physical sciences the problem then stands as follows: How can our narrow criterion, according to which all the scientist verifies are simple statements about the positions of pointers and the shapes of instruments, be reconciled with the obvious fact that physicists very confidently and successfully use such abstract things as 'electrical field' and 'elasticity coefficient,' and such theoretical conceptions as 'atom' and 'probability wave' which no-

body ever expects to see or touch like physical things. It will be noticed that a further distinction has just been introduced by referring to 'electrical field' as a relatively abstract, and to 'atom' as a theoretical, concept. The two terms, 'theoretical' and 'abstract,' have not been used at random.

What is the meaning, according to the empiricist criterion, of the abstract terms such as 'electrical field,' 'electrical current,' and 'elasticity coefficient?' These terms do not directly refer to physical objects and their immediately observable properties. There is thus still a problem left. But let us now ask under what conditions a physicist asserts the presence of an electrical field around a conductor or of a current in a wire. The wire and the conductor are indeed physical objects, and statements about their motion, for instance, are of the simplicity and concreteness which our meaning criterion requires. At this point the idea and the direction of the empiricist analysis become clearly visible. Physicists say that a conductor, that is a certain physical thing, generates an electrical field if, and only if, under specifiable conditions, something directly observable happens to other physical things in its neighborhood. The electrical current, in turn, is recognized, as one usually says, either by the movement of a magnetic needle in its neighborhood, or by the heating of a resistance, or by the sedimentation of a solid substance out of a so-called electrolytical solution. Customarily one speaks of these three alternative, immediately observable events as effects by which the presence of the electric current is recognized; logically, however, this is putting the cart before the horse and one should rather say that what is meant by the presence of an electrical current in a wire is, first, that whenever one of the three alternative measuring instruments, magnetic, thermic, or chemical, is put into its circuit, the corresponding phenomenon will be observed and, second, that whenever one of these tests comes out positive, then the other two will also show the expected changes. This kind of analysis is what empiricists refer to as the "reduction of an abstract term to the physicalistic verification basis." Put this way it becomes again plausible enough that even the most abstract terms of the physical sciences, such as 'entropy,' can be thus reduced. Soon it will also be seen why such theoretical terms as 'atom' or 'electron' have so far not been considered. Their reduction requires an additional step which does not occur in the reduction of the so-called abstract terms or empirical constructs.

It has probably been noticed that in order to verify a statement which contains an abstract term the physicist must perform certain operations, in the case of the electric current, for instance, the appropriate manipulation of the measuring instruments. Such operations, however, are again specified in terms of the immediately observable thing level (physicalistic verification basis). It so happens that the empiricist thesis concerning the status of abstract terms or empirical constructs is best known under the name of "operationism," a term suggested by the manipulations just mentioned. What it asserts can now be expressed in the following manner: In order to have scientific meaning, an abstract term must be operationally introduced from the physicalistic verification basis. The terms 'introduced' and 'reduced' are here obviously used as correlatives.

A physicist, Prof. P. W. Bridgman of Harvard, has popularized the term 'operationism' through his book *The Logic of Modern Physics* (1928). But Bridgman was also careful to point out that operationism hardly deserves to be called a philosophical thesis since scientists, without necessarily being articulate about it, have always practiced operationism. As far as the experimentalist is concerned, this seems a conservative assertion. Bridgman himself drew his inspiration from Einstein's analysis of the concept of simultaneity. This contribution of relativity theory is indeed most conveniently characterized by means of the operationist's terminology. For Einstein has pointed out that the assertion of the simultaneity of two events which are too far apart to be simultaneously observed by the investigator is not a statement simple enough to go unchallenged from our viewpoint and is, therefore, in need of operational reduction.

Concepts and laws. The principles of

methodologically correct definition of abstract terms or concepts are, indeed, all operationism is concerned with. Historically and psychologically speaking, the creation of helpful concepts is, of course, a very essential part of any scientific achievement. But let it also be noticed that if a concept is correctly defined, it is therefore not necessarily helpful. A person's weight multiplied by the number of his hairs and divided by the third power of his blood count is a correctly defined empirical construct, and still one can safely predict that it will never receive any attention in science. The reason for this is that there are no known empirical laws which connect this rather gratuitous creation of my whim with other concepts, as pressure, volume, and temperature are connected in the formula of Boyle and Charles, or which would assert its constancy, as Newtonian mechanics asserts the constancy of mass. Systematically, however, this way of speaking again puts the cart before the horse. A concept appears questionable to us if, and only if, there are no known laws about it; and it seems even gratuitous or absurd when we do not expect ever to find such laws. Expectations of this kind are, of course, nothing absolute but merely a rather general frame of reference or a thought habit dependent upon the laws actually known at any given moment in the history of science. Much of what scientific empiricists object to in traditional philosophy are really attempts to legislate in an *a priori* manner as to the necessity, whatever that might mean, of such frames of reference.

Concepts or empirical constructs are merely the tools of science. What these tools are supposed to produce, through systematic, theory-guided experimentation, are the *empirical laws,* that is, the functional relationships between the concepts or, as one also says, variables defined. To say the same thing differently: Empirical laws are found or hypothesized by means of inductive generalization from observation and experimentation.

Scientific laws have something to do with causality and induction, so one might suspect that at this point, in his conception of the nature of scientific laws, the empiricist brings in some of his epistemological views and thus surreptitiously violates our agreement not to descend beneath the basis of common sense which is shared by all, irrespective of philosophical positions. However nonempiricist philosophers might feel on this point, a strong case can be made that nothing of the kind is being done as far as science is concerned. For to the scientist it is obvious that extrapolation from the tested to the untested case, prediction of future unobserved, on the basis of past observed, regularities is, in a certain sense, but a guess, no matter how successful in practice, or, to use Hume's illustration, that in a philosophical sense it is neither certain nor necessary that the sun will rise tomorrow. For the scientist, if not for the man on the street, this is again just common sense followed through to its logical conclusion. Technically this fundamental feature of our knowledge is referred to as the hypothetical or inductive character of all empirical laws.

With respect to causality the situation is not much different, though somewhat more interesting in view of recent developments in physics. One can often hear it said that modern quantum theory, in replacing the causal laws of classical physics by mere probability correlations, has brought about a major revolution in our philosophical ideas. A major revolution it was indeed, but only within science, not in philosophy, at least not as far as the empiricist is concerned. From his viewpoint *causal law* does not say one iota more than *law,* and finding the causes of events means for him nothing more and nothing less than finding the laws or regularities governing their occurrence. For the scientist at least this is again just common sense. A law in turn is, logically considered, a statement of the form, 'If A then B,' or rather, 'Whenever A then B,' the only requirement being that all the expressions which occur in 'A' and 'B' are operationally defined. For if they were not, how could we test the law or even know what it means? But it makes no difference whether the regularity which the law asserts obtains between so-called individual events or between statistical frequencies. What, for that matter, is an individual event? Frankly,

this question is much too difficult to be tackled here.

Scientific theory and explanation. So far we have gained some insight into the two notions of *scientific concept* and *scientific law.* Our attention must now turn to the ideas of *scientific theory* and *explanation.* A scientific theory (high-order explanation) can be described as the logical integration and organization of a whole body of empirical laws. Scientific understanding is the result of scientific explanation. To be specific, when physicists found the three formulae or laws of free-falling bodies, of the inclined plane, and of the pendulum respectively, they also explained these phenomena (low-order explanation). But their understanding was improved when these three empirical laws were shown to be special cases of one set of more general laws, the laws of mechanics. Again, Newton reached a still higher level of explanation when he derived the phenomena of two so far entirely unrelated fields, astronomy and mechanics, from one and the same set of basic laws. But one must not forget that we call these laws more general or more basic only because they allow for such logico-mathematical derivations of other laws. The psychological effect, the increase in understanding attained, is, of course, still more marked if such integrations allow for the prediction of laws so far not even known in isolation. Then we feel that we "really understand."

In a loose, but suggestive manner of speaking, one might say that empirical laws integrate and predict individual facts while theories, in the broader sense of the term, integrate and predict empirical laws. The process of such integration is very appropriately described as a process of unification and so we gain, within the field of the physical sciences, a first glimpse of what could be meant by the unification of science. This process and its results will be referred to as *unification as to theory.*

Theoretical concepts. To understand the nature and function of those concepts which are not merely abstract but theoretical in the narrower sense, such as 'atom' and 'electron', consider, for instance, the two fields of mechanics and thermodynamics. Typical for the one is the Newtonian attraction formula or the law of the lever; typical for the other, the formula of Boyle and Charles, which I have already mentioned, or the formula which connects the boiling point of a liquid with pressure. In order to unify these two fields, scientists have resorted to what has been called the construction of *models.* The gas in particular is thought of as consisting of a great number of particles which are subject to the laws of mechanics. What we observe as gas pressure is said to "correspond" to the total mechanical impulse of those imaginary particles; temperature in turn is specified as some function of their average velocity, and so on through the whole list of the empirical constructs of thermodynamics. To each of them a mechanical property of those imaginary little balls is *coordinated.* The idea of the whole game is that after the coordination has once been made, one expects to derive the thermodynamic laws as special cases from the laws of mechanics by applying the latter to the imaginary particles. If this should work, as it actually does or did within very wide limits, a tremendous step towards unification has been made. Everybody realizes, of course, how sketchy a description of the so-called classic kinetic theory of Maxwell and Boltzmann this is, yet it will serve our purpose. So let me start on a series of four brief remarks of a more general nature.

First, it should be stated that by this so-called mechanical model the operational definition of the empirical construct 'temperature' is not in the least affected, and we also still experience heat as heat. So there need be no fear that the "mechanical" theory of heat has impoverished the world by denying it the warmth and glow, in this case quite literally, of all nonmechanical qualities. This is a useful point to remember whenever one comes across certain very fashionable arguments that science, particularly in the domain of consciousness and culture, impairs the appreciation of the totality of human experience. The situation in these fields is admittedly much more complex, but there is no difference in principle. By explaining, if necessary even in physiological terms, the

occurrence of a value experience, one has neither denied its occurrence, nor challenged the value in question, nor, finally, stripped the world down to the skeleton of a meaningless machine.

Second, one must realize that even when theoretical unification has been achieved, that does not mean that one always has to go down to the rock-bottom level of the most comprehensive scientific explanation. To give an illustration, the engineer who uses the laws of thermodynamics in designing a steam engine does not need to concern himself with the derivation of these laws from the kinetic model or, to borrow an illustration from the biological field, the neurosurgeon will not gain any additional skill by tracing down to the level of the electric reactions of the nerve fibers the causal mechanisms he utilizes. Again, no reasonable person will expect the clinician to analyze the personality traits of his patients down to that level of elementary conditioning which is most pertinent in learning experiments. But one must not forget either that theoretical reductions or unifications are not only intellectually very satisfying but sometimes do lead to the discovery of new empirical laws which prove extremely useful to engineers, surgeons, and clinicians.

Third, it was to such imaginary models as the atom that the term 'theoretical' in its stricter meaning has been reserved, while 'empirical construct' was used for concepts, no matter how abstract, which do not contain any reference to such imaginary things. To put it differently, we want to distinguish between imaginary things and non-things. The problem involved is best understood if one tries to answer the naïve question whether there are really atoms, whether atoms are real, and if not, how an empiricist could justify these brain children of the scientist. One answer at least to this famous question goes about like this: Whatever the philosopher has to say about the meaning of the word 'real,' both scientific and plain common sense require that it must not be interpreted in so narrow a sense as to comprehend nothing but physical things like chairs, stones, and apples. 'Real,' in other words, is not synonymous with 'material object.' Philosophically speaking, there are not only things in the world but also their manifold patterns, structures, and relations. Speaking in terms of physical science this means that forces, electrical fields, and elasticity coefficients are as real as the physical objects which, as we saw, form the operational basis for their definitions. 'Real,' briefly, is for the scientist everything that finds its place in the hierarchy of the empirical constructs. Models, as the gas model described, obviously do not occur in the hierarchy of operationally defined concepts; they are later on coordinated to empirical constructs and are, in a certain sense, merely computating devices or, if you please, *unifying devices* to establish logical connections between various classes of empirical laws. The way the question of the reality of the theoretical particles is often put and treated is, therefore, about as meaningful as to ask whether the Mississippi is male or female. It simply is not a good question and, to use the poignant phrase of one of the most influential living philosophers, "Where there is no question there is no answer."

Atomic theories are probably the most conspicuous technique of explanatory unification. There are, however, other unifying devices. The unification of optical and electromagnetic laws for instance or, as one usually says, the recognition of light as an electromagnetic phenomenon, the great discovery which we owe to the genius of H. Hertz, lies entirely within the realm of the empirical constructs. The reduction of this "theory" requires an analysis of its own.

Fourth, I want to emphasize that the so-called indeterministic character of modern physics lies entirely in the realm of the model. Galton already has called attention to very simple mechanical systems about which no other but statistical predictions can actually be made. The point is that in spite of this we used to refer everything, at least in principle, to a universal atomic model between whose elements laws of the Newtonian rather than of the statistical frequency type obtained. The resulting difficulties which finally led to the abandonment of the model have sharpened our insight into the purely fictitious or calculational charac-

ter of models in general and, in addition, have helped us to clarify, rather than to revolutionize, our notion of scientific lawfulness. As to the claim which hides itself behind the phrase "in principle," we have learned to recognize it as an empty verbalism wherever it pretends to go beyond the limits of the operational basis.

The system of the sciences. We are now ready to examine what insight we have gained so far into the *system* of the sciences. Are there physical sciences, different theor*ies,* on the one hand, and concepts and empirical laws of different categories on the other, or is there, if one considers the matter from the vantage point of the philosophical methodologist, only one physical science, one unified body of theory; is the logical nature of all kinds of empirical constructs and empirical laws the same? If the problem has once been focused this way, it becomes apparent how ambiguous the issue of the unity of science is and how easily therefore its discussion can lead to confusion, if one approaches it without preparatory analysis of the kind here indicated. One really has three questions on hand, one as to *concepts,* one as to *laws,* one as to *theories,* and the answers to them are not necessarily either all positive or all negative. The last question, as to unity of theory, is not even of the same general character as the first two concerning concepts and laws. More specifically, unity as to theory is entirely a question of fact, that is, of actually achieved theoretical unification, while the question about the status of laws and concepts allows for an answer of comparatively much greater or, if you please, philosophical generality. And now for the empiricist answer itself. According to it there is only one legitimate way of defining scientific concepts, the way of operational definition from the physicalistic verification basis; and there is only one way of analyzing any empirical law whatsoever, the analysis into a universal if-then correlation ('Whenever A then B') between empirical constructs. As to theory, the extent to which, through coordination of models or through other logico-mathematical devices, these laws can actually be integrated into a unified body of deductive consequences from a relatively small number of so-called basic laws, cannot be determined on logical or methodological grounds. For physics and chemistry, though, the scientific developments of the last two generations have furnished an affirmative answer to this question. Notwithstanding the many problems which are the concern of the specialist, the theoretical or the explanatory unity of physico-chemistry is today a fact. This being the case, one might wonder why I spent so much time on the discussion of an area which is already organized, instead of concentrating on the biological and behavior sciences which, since they are less accomplished, may stand in greater need of philosophical clarification. To this I should answer that only by studying the structure of physical science can one provide himself with the instruments which will guide him through the metaphysical fog which, partly because of our relative ignorance, partly because of what sociologists call the cultural lag, still sometimes beclouds a clear methodological understanding of the nonphysical sciences.

The phenomena of purpose and consciousness. The empiricist position on these much more debated issues is that, in order to be of scientific significance, all concepts, no matter where they occur, must be operationally defined in terms of the physicalistic verification basis; that science, whenever it tries to explain or understand, must look for empirical laws, and that therefore all scientific laws, no matter in which field they occur, are of the type of a universal if-then correlation, for otherwise they could not allow for prediction. In other words, as far as laws and concepts are concerned, the methodological unity of science is for the empiricist again just common sense, though it is admittedly not common sense for many a contemporary student who adheres to one of the older philosophical systems. Though the objections raised against the empiricist thesis are very variegated, the whole cluster of them is well represented by the belief that both the concept of purpose and the concept of consciousness defy any attempt at reduction to the physicalistic verification basis. The objection of purpose already arises in the biologi-

cal sciences, that of consciousness is most frequently voiced in connection with human behavior

Before taking up these objections, let us recall that we are not here concerned with epistemological analysis below the common sense level. All we have to do is to answer the question: under what conditions does the scientist describe the behavior of an organism as purposive or attribute conscious states to one of his human subjects? Sometimes it is factitiously alleged that modern science denies the *phenomena* of purpose and consciousness, and that modern empiricism, abetting it, tries to furnish the philosophical justification of such outrageous nonsense. In matter of fact, modern science does not eliminate or deny purpose and consciousness any more than the kinetic theory eliminates or denies the phenomena of heat. As an *epistemology* modern empiricism deals with purpose and consciousness in its own manner, which one could very, very roughly characterize as a refinement of Hume's approach; by doing so it puts itself into a position to appreciate, as a *philosophy of science* or on the common-sense level, the meaning of the question that has been formulated a moment ago: What does the scientist mean by purpose and consciousness? This again, as we have learned from the discussion of physical science, is equivalent to the question: How does the scientist recognize their occurrence and how do these concepts enter into laws which lend themselves to the only purpose of science, namely that of prediction?

To be sure, then, purposiveness or, to use a less anthropomorphic expression, adaptability is one of the most outstanding features of organisms. The exploration of whatever can be said about the *purpose of Nature* the scientist as well as the empiricist may safely leave to the old-style metaphysician, but they will certainly have to account for the occurrence of purpose in nature; that is, for the goal-directed behavior of those physical objects which we call organisms. Everyone even slightly familiar with modern psychology knows that at the present stage of our knowledge the most direct way to the exploration of this field leads through the systematic study of the learning process. There one finds, on the common-sense level, such statements as that organisms learn or act purposively toward the attainment of a goal, if, and only if, their motivation is directed towards that goal. But let us ask ourselves whether this formulation, the way it stands, is an empirical law, or, to put the same thing differently, whether it has any predictive value. All it says, it seems to me, is this: whenever the organism does show certain kinds of objectively describable behavior towards certain objectively describable states of affairs or objects, then we say that it has been appropriately motivated; if not, not. But this is clearly no more than a descriptive account, in empathetic terms, of what has happened, *after* it has happened, not a prediction of what is going to happen. What the scientist tries to find, in order ultimately to control them, are, therefore, just those objective factors in the organism's past and present environment which elicit that behavior which we then, in prescientific language, call purposive or ascribe to the organism's motivation. Only on the basis of such knowledge can one predict; that is, after these factors have been found, laws can be formulated and this without any use of such terms as 'purpose' or 'motivation.' In other words, this paragraph itself is an informal sketch of the actual reduction to the physicalistic verification basis of the two crucial and allegedly irreducible concepts. In technical terminology 'purpose,' 'motivation,' and the like, turn out to be so-called dispositional concepts, the elimination of which does not restrict the expressive potentialities of our language.

Turning now to the notion of consciousness, all one has to find out is again under what conditions scientists or clinicians speak about conscious states of their subjects. And again the answer is sheer common sense. All we have to go by if we ascribe consciousness to a subject, or, to say the same thing differently, if we use mental terms, such as 'feeling,' 'knowing,' 'believing,' in the description of his behavior, is this behavior itself. Behavior, however, including speech behavior, can be described in terms of the pysicalistic verification basis. This aspect of the empiricist position is best known under the name behaviorism. But to say anything worth while about behaviorism would require

at least another article of the same length. So I shall content myself with the mere reference to this well-known position which is accepted by all contemporary psychologists with the sole exception of the small German-influenced group of the Gestalters.

Vitalism and mechanism. While the empiricist thesis in the behavior field has been labeled as behaviorism, a similar tie-up with well-known positions in the biological field has been omitted. The labels which here come to mind are, of course, those of mechanism and vitalism. On first sight it might appear that the mechanistic thesis is an integral part of the empiricist position. Such belief would be mistaken. The situation requires further analysis in the light of the threefold schema of concepts, laws, and theories. It is true that vitalists and related writers often take their stand on the alleged irreducibility of the concept of purpose and, in connection with this, assert the existence of so-called teleological laws. Nothing more needs to be said about the alleged irreducibility of purpose. As far as teleological laws are concerned, purely logical analysis reveals that this unclear notion cannot even be precisely formulated. Thus a question of fact never arises. With respect to unity of theory, however, the thesis of vitalism can—irrespective of its truth or likelihood—at least be formulated in a manner which makes sense both to the scientist and to the empiricist philosopher.

This brings us to the issue of a theoretical unification of all three levels: physical, biological, and behavioral. Clearly and in contradistinction to the situation within the physical sciences, such unification has as yet not been achieved. Even within each of the two higher levels, we do not yet possess comprehensive bodies of empirical laws, or at least not bodies of laws the significance of which we could trust in the theoretical sense that they are certain to provide the cues for a potent and comprehensive theory after the manner in which Galileo's findings provided a basis for Newton's theoretical achievements. As long as this is the case, actual explanatory unity as to theory between all the three levels is *a fortiori* impossible. The point is rather that philosophical mechanism and philosophical vitalism both defeat their own purposes by furnishing *a priori* arguments for matters of fact, the one for the impossibility, the other for the necessity of an ultimate unification as to theory.

To mechanism one must grant this: as to laws and concepts, the unity of all science is a fact, not a program. If this is once clearly understood, the props are indeed knocked out from under the better part of the vitalistic speculation and from under the pronouncements of the Gestalters. To vitalism, on the other hand, one must grant that much: it is perfectly conceivable that in its attempts to describe the physical processes in those tremendously complicated systems which we call organisms, scientists will discover new physical laws which are not theoretically reducible to the already known basic laws of physics and would, therefore, have to be added to them. It is, however, not the case that the mere occurrence of the phenomena of purposive behavior and of consciousness justifies such an expectation. Quite to the contrary, the whole frame of reference of modern science, the vigorous growth of such disciplines as biophysics, biochemistry, physiological psychology, and the theory of learning strongly indicate the improbability of what has here been exhibited as the formulable empirical core of the vitalistic contention. In this sense mechanism may indeed be said to be an essential part of our scientific and cultural frame of reference. But the modern analytical philosopher is neither the ideological defender nor the fact-finding supporter of such frames of reference. His job is to sharpen their formulation and, by doing so, to clarify their meaning. In the case of vitalism versus mechanism the result of the analysis is that we are here not faced with a philosophical issue *about* science and still less, as some factitiously contend, with a cultural issue, but rather with a very vague negative prognosis concerning the result of future research *within* science. Since the general cultural context has thus come up again, it will, I hope, not be inappropriate to conclude by expressing the conviction that the intellectual caution, care, and cleanliness upon which empiricism insists in such analyses, is itself a major cultural value.

AIR-BORNE SPORES AND PLANT QUARANTINES

By W. A. McCUBBIN

In estimating the ultimate worth of plant quarantines as a means for the permanent exclusion of injurious plant diseases from the United States, it is necessary to take carefully into account the possibility of spore dissemination over long distances in air currents. When it is considered that spore dissemination by air is entirely uncontrollable and that air movements on a large scale are a universal and constant feature of nature, the question may be raised: Is natural air transport effective enough to lessen materially the value of these quarantine efforts, at least for some diseases? Or does long-distance air transport of spores involve such difficulties and limitations that it may be largely ignored in planning plant quarantines?

In attempting to review the essential elements of this problem we are confronted at once with the difficulty of trying to maintain in correct perspective in a single mental picture two such extremes of size as our huge planet and a microscopic spore; fortunately, this mental feat can be made somewhat easier by some preliminary discussion of each extreme.

We unconsciously tend to regard the air overhead as a limitless expanse, extending almost indefinitely above us into space. This vague idea serves well enough in ordinary affairs, but when we attempt to grasp the conditions attending the air movement of spores, it is necessary to obtain a more accurate concept of our earth's atmospheric envelope.

On a planetary scale the terrestrial air blanket consists of only a thin and scanty covering of gaseous materials held tight to the earth's surface by gravitation. As air is highly compressible, its lower level is relatively dense, but the mass thins out rapidly upward. At a comparatively short distance from the surface the gaseous matter becomes so dispersed and tenuous that the air occupying the uppermost portion above about 40 miles is, from our point of view, of little importance. About 25 miles from the surface an ozone region is said to exist, which screens out virtually all the destructive short-wave components of sunlight; however, the longer light waves penetrate readily to the earth's surface, where they are reflected, absorbed, or transformed into heat. The air mass in direct contact with the earth will, therefore, be denser, warmer, and more disturbed by thermal activity, resembling in this respect the air immediately above a hot stove. A multitude of convection currents, both vertical and horizontal, abound in this lower layer, and tend to distribute the surface-generated heat. The thermal system thus set up functions somewhat on the pattern of what goes on in a kettle of boiling water.

We may get a clearer comprehension of the actual spatial relations of this terrestrial air layer by imagining our earth reduced to the size of a 12-foot sphere. On a world of this size the atmospheric blanket would extend outward at most 3.5 inches from the surface; the more compact, lower 40 miles, dense enough to be of interest in our problem, would reach only $\frac{3}{4}$ inch from the surface; the ultraviolet filtering region would begin less than $\frac{1}{2}$ inch up; the lowest 7 miles, containing practically all storm and weather disturbances, would have a ceiling of $\frac{1}{8}$ inch; and even in this thin shell most of the weather phenomena and most of the fungus-spore movement would be found in the lowest 3.5 miles, or in a thin skin $\frac{1}{16}$ inch deep. On this same scale the long stretch of plains country extending from Mexico to the Canadian border would represent approximately 20 inches; the 3,000-mile Atlantic hop, 54 inches; and the 5,000-mile expanse of the Pacific, 90 inches.

In the light of these conditions it would obviously be incorrect to visualize air-borne spores as shooting off into illimitable space like the rocket ships of fiction and eventually falling back to earth again far distant from their point of departure; rather we must picture them as trickling along in a horizontal course, almost hugging the surface, and confined in a thin lower layer of the air, where they are subject to all the disturbances and

vagaries of this most turbulent portion of the atmospheric envelope.

Turning now to the spores themselves, we find that, although they consist of vegetable matter comparable in density to apple or wheat tissue, their minute size brings them into the dimensional plane of dust particles, a plane in which certain physical relations become markedly altered. In a series of objects of the same shape and substance but decreasing in size, the volume or mass decreases much more rapidly than the area. If we recall further that the downward pull of gravity is proportional to mass, while the resistance of air to bodies passing through it depends on their area, it is apparent that as size diminishes, air resistance will have a rapid increase relative to gravitational pull. This increasing disproportion between air resistance and gravitational pull becomes very pronounced at the size level of dust and spores, so that spores tend to fall very, very slowly.

The rate of fall in still air has been determined experimentally for a number of spore types. An oval spore measuring 20×12 microns could be expected to have a falling rate such that if it were released at a height of 1 mile, 3 days would be required for it to fall to earth.

This surprisingly slow rate of fall is, of course, a basic point of departure for estimating the possibilities of long-distance transport; theoretically a 20-mile breeze could carry the spore example just cited 1,440 miles across country while it was falling to earth from its mile-high point of release.

Such calculations of rate of fall, however, do not themselves bring us to any final conclusions in the problem of long-distance spread. They merely serve to establish its possibility, and particularly to convince us that, because of this feeble tendency to fall, fungus spores in general are capable of being transported in favorable air currents to almost any distance over the earth.

Having thus touched on the salient characters of the air as a carrying medium and the fungus spore as a particle to be transported, we may proceed to consider the vast number of plant pathogens awaiting transportation at some foreign point of origin, the conditions affecting spores throughout the course of a long air journey, and the possibility of successful establishment on their arrival at a distant destination.

Starting with the situation at the point of origin, we are able to conclude at the outset that spores of certain diseases would be airborne with difficulty or not at all. Examples include potato wart, common scab, rhizoctonia, powdery scab, and blackleg of potato, and diseases of other plants such as crown gall, club root, and many wilts. All these are so bound up with the soil that the chance of spores getting aboard air currents in appreciable numbers is negligible.

Again, many pathogens remain so immersed in host tissues that long-distance spread is almost precluded; such troubles as the Dutch elm disease, pear blight, various virus diseases, and nematodes belong here. The nontravelling class also includes a large group of fungi with dispersal arrangements primarily adapted to water dissemination. The very numerous species of *Gloeosporium* and *Cylindrosporium* are good examples. Mention must also be made of fungi that normally sporulate in such sheltered locations that it would be difficult for their spores to get into air currents. Spores sensitive to drying out and those with extremely short natural periods of longevity may also be left out of consideration for long jumps.

What proportion of disease organisms will fall into this stay-at-home group? Although no exact answer is possible, we may get some light on the general situation by the sample-analysis method. Selecting as a sample the list of 200 representative diseases already assembled for another quarantine-analysis study, it is found that, for one reason or another, from 75 to 90 percent of them appear to be incapable of more than limited or local distribution through the air. Conditions in this sample indicate, therefore, that long-distance transport as a quarantine problem narrows down to a comparatively small percentage of pathogens peculiarly adapted to this type of dissemination.

The ascension of spores into the air at the point of origin presents no difficulty. The slightest convection movements, such as are constantly present everywhere, involve velocities far in excess of the feeble falling

tendency. A barely perceptible breath of air moving at 1 mile per hour dwarfs into insignificance the falling speed of the spore previously cited, which is 72 feet per hour. Thermal convection masses, therefore, can readily carry spores upward to whatever height these masses rise, and thus bring them into favorable position for extended horizontal travel.

Horizontal travel, however, is attended by many uncertainties. Downward convection currents may carry the spore rapidly to earth again; winds die out or change direction; desiccation may fatally affect some spores; low temperatures fatal to a few spores occur at altitudes comparatively near the surface; and sunlight, known to be damaging in some cases, has a more intense effect in the upper regions, although spores are unlikely to be carried up to altitudes of 25 miles or more, where they would be subject to extremely deadly ultraviolet radiations.

Spores adrift in the upper air currents are subject to two other major obstacles to extended transport. By virtue of an acquired electric charge each spore serves readily as a nucleus for moisture condensation, so that when vapor-laden air carries a spore to cloud-formation levels and is chilled, either by mere expansion or by contact with colder upper air masses, the spore is likely to find itself locked within a water droplet. And if condensation progresses to the stage of rain, the included spore is inevitably carried back to earth in the falling drop. Observations indicate that just as rain clears the air of floating dust, it is equally effective in washing down drifting fungus spores.

High mountain chains are a second formidable obstacle to spore travel. When air masses carrying spores are deflected upward by mountains, the cold of altitudes at or near the summit is favorable to moisture condensation, which is likely to bring the spores to earth in rain, mist, or snow.

When a fungus spore finally comes to earth 1,000 miles or more from its starting point, after an erratic period of helpless drifting, it is confronted with still other difficulties. Unless it can happen upon a suitable host it is lost. For the visiting spore not only are sandy wastes, plowed fields, snow blankets, and water expanses utterly barren, but even a vast and luxuriant nonhost flora constitutes an equally hopeless prospect; in fact, any new environment may be largely an inhospitable desert, where a spore's chances for reaching small or scattered host plants are extremely minute. The chance that an individual spore would both survive extended transport and establish successful infection is so infinitesimal that distant migration would have to involve almost incredible numbers of spores in order to bring success for even a few of them within any reasonable degree of probability. One may therefore surmise that only those fungi capable of charging the air with a tremendous spore load will have any appreciable chance for successful long-distance spread.

Other difficulties beset the newly arrived spore. It may reach its destination at the wrong season, the host may be in a resistant or dormant stage, conditions for infection may be adverse, either winter or summer climate may be too severe, or a necessary alternate host may be lacking. If the fungus species represented by these spore immigrants can live saprophytically for a time, or establish a more or less permanent relation with its host, or propagate itself immediately by several rapidly produced generations, its chances for developing a slight foothold into permanent invasion are vastly increased. But spore mortality is so high and the requirements for bridging interseason gaps are usually so exacting that, unless the spore possesses some special advantage, light initial infections are likely to die out completely.

Looking at these peculiarities of behavior from the plant quarantine point of view, it is encouraging to note that, so far as long-distance spread is concerned, most plant diseases belong to the stay-at-home group. It is equally encouraging to note that the probability of intercontinental dissemination become appreciable only for fungi with a large scale initial spore production; comparatively few fungus species can qualify in this respect. The feeble rate of fall, associated with the small size of spores, assures us that spores can be carried upward with the greatest ease in even slight convection currents and that the possibility of horizontal travel in wind is al-

most unlimited. It is some comfort, however, to observe that the course of air-borne spores is relatively close to the earth's surface where the spore load is subject to constant and severe depletion in the turmoil of this thermally active contact layer. Finally, even for species that possess favorable qualifications for travel, the overseas trip is very much of a gamble, because it involves a series of uncertainties, practically all of which must come out favorably to bring success. Distant air travel by fungus spores is therefore made against heavy odds.

For easier comprehension, we may translate this general situation into a scale of more familiar terms. Imagine an extensive flat garden roofed over with glass at a height of 6 feet. An experimenter stands at one side with an electric fan and a cupful of brown rot spores which he is attempting to blow toward ripe peaches on a tree about 300 yards away, in the hope of infecting them. Stretched across the garden midway to the peach tree is a 5-foot privet hedge and an overhead sprinkler system at work. The chance of any of his spores infecting the peaches under these conditions represents in a rough way the chance of a spore's making a successful jump of 1,000 miles in air currents over the earth's surface.

It is apparent, therefore, that against the relatively small number of foreign fungus species endowed with all the requisites for successful dispersion by air, our chief protection lies in this very matter of probabilities. It is possible that any of these species could be lucky throughout the whole series of events en route, though ordinarily their chance of success is probably very small. In any case, the slight possibility of disease introduction by air is judged to be far too small to affect materially the worth of the plant quarantine effort, the primary concern of which is to prevent disease and insect introduction from other world regions overseas by establishing a watchful supervision over the controllable channels of human travel and commerce.

FEDERAL PLANT QUARANTINES

Before

The United States is the only great power without protection from the importation of insect-infested or diseased plant stock. . . . A properly enforced quarantine inspection law in the past would have excluded many, if not most, of the foreign insect enemies which are now levying an enormous annual tax on the products of the farms and orchards and forests of this country. . . . In addition to the danger of importing these insect pests is the risk of bringing in new and dangerous plant diseases. . . . The necessity for a national quarantine against foreign insect pests and plant diseases has long been recognized, and during the last 14 years, especially, a strong continued effort has been made to secure such legislation. . . . The first concerted effort to obtain a national quarantine and inspection law was due to the introduction in the East on nursery stock of the San José scale in the early 90's. The failure to reach an agreement as to suitable legislation among the nurserymen, fruit-growers, and entomologists prevented anything coming from this effort, although several bills were introduced in Congress from time to time. . . . The present effort to secure legislation resulted from the discovery two years ago of the introduction of enormous quantities of brown-tail moth nests, full of hibernating larvae, on seedling fruit stock, chiefly from northern France.

After

The need for national quarantine legislation for the protection of the farm, garden, and forest interests of this country from further invasions by foreign pests was long appreciated, but the securing of this legislation necessitated an extended period of earnest effort. Toward the end of this period this legislation was hastened by the increasing numbers of gipsy and brown-tail moths found during the years 1909–12 on imported plants, and also by many other insects and plant diseases and by the need, which began to be generally appreciated, of excluding such other important pests as the Mediterranean fruit fly, the potato wart, and the white pine blister rust. The movement was aided also by the experience with the chestnut blight and the San José scale. The entry of the citrus canker, the Japanese beetle, and the European corn-borer all occurred during the last years of the effort to secure this legislation and before it was actually enacted, although the fact of the entry and establishment of these pests was not determined until several years later. The Plant Quarantine Act of 1912 was the final outcome of this 14-year effort to secure authority to protect the United States, so far as possible, from further entry of plant pests. In connection with broad quarantine and regulatory powers, this act makes specific provision for the regulation of the entry of nursery stock and other plants.

By C. L. Marlatt, "the father of the Plant Quarantine Act of 1912." Quoted by permission of the National Geographic Society. Left, from the *National Geographic Magazine*, Apr., 1911; right, *ibid.*, Aug., 1921.

SCIENCE ON THE MARCH

ETNA CAVE, NEVADA

WORK in various phases of the problem of the pre-Columbian occupation of the southwestern United States has practically come to a standstill as a result of the war. Information pertaining to investigations carried on prior to the outbreak of hostilities is gradually becoming available, however, and serves to stimulate continued interest in the subject. One of the lesser known, although significant, archeological projects in this category was that at Etna Cave, located about 6 miles south of Caliente in Lincoln County, southeastern Nevada. Excavations in its deposits demonstrated that it had been inhabited at different times by various groups extending from the late developmental period of the Pueblo peoples—the stage just preceding the era when the large communal houses and cliff dwellings whose ruins dot the Pueblo Plateau were built—back to the days when the native horse, camel, and giant sloth roamed the countryside.

The cave is situated in a narrow canyon, lies within a wall of volcanic tuff at the top of a short, steep talus, and faces southeast. Its entrance is protected by an overhanging cliff which also extends some distance towards the southwest and forms a shelter area along the top of the talus. Mr. J. B. Tennille, a prominent resident of Lincoln County, originally called the attention of Mr. S. M. and Mrs. Georgia Wheeler, then located at the Panaca, Nev., CCC camp, to the formation and its archeological manifestations. The Wheelers made a preliminary inspection, did some testing, and reported their findings to officials of the Southwest Museum, Highland Park, Los Angeles. This led to arrangements between the Southwest Museum and the National Park Service for a program of excavations at the site. Boys from the Panaca CCC camp were used for the work. The digging was carried on under the general supervision of Mr. M. R. Harrington, curator of the Southwest Museum, with Mr. Willis Evans in direct charge. Most of the formerly occupied area was uncovered by that group, although a small section left to serve as a control was completed two years later by a party from the Southwest Museum.

The cave showed a sequence of temporary occupations, but the shelter only gave evidence of use by the Pueblo peoples. The excavations indicated that in the beginning the cave had been visited at frequent intervals by a nomadic hunting people who made it a camping place rather than a permanent habitation. It is not known who these people were. Their weapons and tools, however, suggest that they may have been contemporaries with other early hunting groups—such as the so-called Folsom men and the occupants of Ventana Cave in southern Arizona—whose material culture is found in association with the remains of extinct species of animals under conditions indicating a terminal Pleistocene or beginning Recent geologic age. For some reason these visits ceased. There was an interval during which the accumulation of refuse was covered by a natural layer of dirt and debris that was gradually tramped down by the feet of animals until it formed a hard-packed "floor" throughout the cave. There is no scale by which to determine how long a period this unbroken stratum represented, but it probably was of considerable duration.

Other wanderers drifting into the area then came upon the cave and a new cycle of inhabitation followed. Artifacts found in the layer formed from their debris indicate that they were related to the people who once lived in Gypsum Cave, located in a spur of the Frenchman Mountains east of Las Vegas, Nev., about 100 miles to the south. Previous work at the latter location by Mr. Harrington had revealed that the oldest inhabitants there had hunted the ground sloth (*Nothrotherium shastense* Sinclair), camel (*Camelops* sp., and *Tanupalama* sp. of which two species are probably represented), and possibly were acquainted with the horse (*Equus* sp., a small form, and *Equus* sp., a large horse, cf. *occidentalis*). Contemporaneity between the artifacts, the ground sloth, and the camel was demonstrated, but there has been some

doubt concerning the horse. Other caves, such as Smith Creek Cave and Upper Baker Creek Cave in White Pine County, Nev., some 100 miles north of Etna Cave, also indicated that these early hunters might have known the native horse yet did not establish that fact. In Etna Cave there was evidence for such contemporaneity. No horse bones were found, but in the level containing the artifacts similar to those from Gypsum Cave were scattered feces that have been identified as horse dung. Analysis has shown that they were a winter product from a small animal or animals that had been feeding on yucca, brushwood, and other unsucculent food. It appears that the horse sought shelter there during an interval when its intermittent human tenants were elsewhere, although they subsequently returned before their ultimate disappearance from the district. Hence it is logical to suppose that they must have seen occasional horses even though they had no direct contact with them. Were it not for the overlying strata and their archeological content the traces of horse could be attributed to post-Columbian times. Evidence from the subsequent deposits, however, is against such an explanation. It must have been a native and not a European horse. The top of this layer was covered by a "floor" similar to that capping the bottom level.

Above the second "floor" was a layer of dust, debris, quantities of dried grass, shredded juniper bark, yucca leaves and fibers, corncobs, and other vegetal material. It contained numerous artifacts and discarded articles that identify the horizon as that of the Basket Makers, the group of people preceding the Pueblos in the Southwest. Two phases were represented in the layer. In the lower portion the objects were indicative of the true Basket Makers, while the upper contained materials indicating progression to the late or Modified Basket Maker stage when pottery making and increased agricultural activity had become a part of the culture. The characteristics of both phases of the Basket Makers are well known from work in their remains in the Four Corners area of Utah, Arizona, Colorado, and New Mexico and their relative ages have been established. They antedate the Spanish pentration of the Southwest by 700 to 1,000 years. This material was also sealed in by another of the hard-packed "floors."

An appreciable lapse of time seems indicated by this upper "floor," both in its formation and a subsequent period of disuse, because the cultural material occurring in the layer above is characteristically late developmental Pueblo, Pueblo II as it is sometimes called, in form. There was no early developmental Pueblo horizon in the deposits, hence the break must represent a minimum of several generations or, what is more likely, one to two centuries. The absence of early developmental Pueblo manifestations is a condition commonly found in Nevada and probably is attributable to the fact that it was peripheral to the main centers of Pueblo growth and was slow to feel their influence. It was not until the cultural pattern had become firmly established in nuclear portions of the Pueblo area that it began to diffuse westward and by the time it reached eastern Nevada was in the late stage of its developmental phase. Even when allowance is made for a similar lag in the case of the Basket Makers, there is a definite hiatus. The Pueblos probably occupied the cave proper only during inclement weather. Most of their time appears to have been spent outside on the talus where, under the shelter of the overhanging cliff, they erected rough retaining walls of stone, levelling the areas between with a fill of stones and rubble, to form a series of terraces where they placed their storage pits, built a fireplace, and carried on domestic activities. Potsherds found there and in the upper level of the cave are characteristic of the ceramic types in vogue during the late developmental Pueblo period and demonstrate contemporaneity in the use of the shelter and the cave. No earlier material was found in the shelter. The top several inches and recent surface of the deposits in the cave had been disturbed, but they gave no indication of aboriginal occupation subsequent to that of the Pueblo II group.

On the basis of the dendrochronological time chart, the tree-ring calendar, developed for the Pueblo area and allowing for peripheral lag, it seems probable that the Pueblo horizon in the cave belongs in the 11th century. The Basket Maker occupation would

date from about 500 to 800 A.D., and the earlier horizons would antedate the Christian Era. From geologic studies made in the area at the time of the Gypsum Cave investigations the oldest human material there obtained was judged to be about 8,000 years old. The second period of occupation in Etna Cave would be approximately the same age, while the first tenants may have preceded them by several centuries. When the native horse, camel, and ground sloth became extinct is not known, but they seem to have persisted longer in this district than elsewhere. In any case it is quite likely that the two bottom levels in Etna Cave are Early Recent in age.

The materials obtained from the cave were divided between the Southwest Museum and the Boulder Dam State Park Museum at Overton, Nev., and may be seen at those institutions. Items about the work were printed in the Masterkey, bi-monthly publication of the Southwest Museum, and a detailed report prepared by Mr. S. M. Wheeler was issued in a limited mimeographed edition by the Nevada State Park Commission at Carson City in 1942.—FRANK H. H. ROBERTS, JR.

THE CASE OF TELEVISION

WHILE military expediency must still enshroud in secrecy much of the startling progress that the science of electronics has made in the last few years, we may anticipate that the effect of this progress will be rapid in postwar years. Probably the general public will be most conscious of developments in the field of television.

This progress in electronics will make possible such vast improvements upon prewar television that perplexing problems will inevitably be raised of both an economic and legal character. Prewar television was already on the market before the war and was sufficiently good to give satisfactory entertainment. The reproduction on the screen of the receiver was made up of twenty-five thousand picture elements, corresponding closely to a ten-inch half-tone engraving, made up of fifty-five dots in the linear inch. Postwar television will make possible five hundred and eighty-five thousand picture elements, corresponding to a half-tone engraving with eighty-five dots to the inch, and therefore render a vastly superior reproduction.

To realize these new possibilities in reproducing a picture of much finer texture, and in natural colors, there will be needed a sixteen megacycle band-spread in the radio spectrum of frequencies, as compared with the six megacycle band used in prewar television. The Federal Communications Commission is already studying the problem of the advisability of allowing a sixteen megacycle band to television broadcasters, for every megacycle band is jealously guarded throughout the radio frequency spectrum.

Unfortunately the problem is not merely a technical one but one of economics as well. For it is not possible to bring about these improvements in television by any adaptation of old standards. The proposed postwar improvements will render obsolete some two hundred million dollars' worth of investment in prewar television equipment. Manufacturers who were already in production of television sets, when the war interrupted, stand to lose, as do also those who have invested in television receivers made under prewar standards. If the public are to be protected against premature obsolescence of their television receivers, then the proposed improved television may be indefinitely postponed, for it appears at present that the broadcasting of television on the new standards is wholly incompatible with maintaining prewar television.

Not only will the consuming public who have already bought television receivers be involved, but it is estimated that the manufacturers and broadcasters have twenty million dollars already invested in television equipment that will become obsolete when the improved standard is adopted. On the other hand, to adopt the new standards of television immediately after the war will necessitate a considerable lag in merchandizing before new equipment can become available. This unpleasant interval may be shortened if through the cooperation of government and industry the new and better picture can be demonstrated within a year after the close of the war. In the meantime present broadcasters could continue to supply programs to those who already have prewar

television receivers. When the new system is inaugurated, old transmitters would be shut down and the prewar receivers would become immediately obsolete and unworkable.

Under the new system, however, television would undoubtedly enter a era of expansion never possible on the old system. One may well remember that the good can often be the enemy of the best, and it would appear that the financial loss and inconvenience that would be entailed in the change-over would be a relatively small price to pay for so great an improvement in the art. In the long run the American public will seek the best that science can offer. Television would not appear to present any exception. Probably those who have already invested in television equipment realized that this new art was in the pioneer stage and such adventurers will be the first to be eager to replace, even at considerable loss, obsolete equipment with new equipment of such outstanding improvement as appears possible under the proposed standards.

The question is naturally asked whether improvements cannot be made in the existing television band without sending to the junk pile millions of dollars worth of equipment. Our engineers differ as to the degree of improvement that can be effected without complete abandonment of the old standard. There seems little question that bigger and better and more realistic reproductions will be possible only on the proposed new frequency band. It is not at all unlikely that the proposed sixteen-megacycle band-spread could be curtailed to fourteen megacycles without unduly cramping the 9.5 megacycles within this band necessary to produce the picture itself. The use of side band transmission methods, already developed by General Electric and the American Telephone and Telegraph Company, may make this possible under the proposed sixteen-megacycle requirement. Color pictures with nine hundred thousand elements would then be practical, and the advantage in realism of introducing color is obvious.

The coming of television to the motion picture theater is not far off. Under prewar standards a television picture blown up to fill a twenty-foot theater screen would probably be too coarse to view at a distance of less than eighty feet. On the other hand, the proposed postwar pictures could probably be viewed at a distance as close as forty or fifty feet, representing a difference of ten rows of seats. Similar advantages would ensue in the projection of television pictures on the three- or four-foot, conventional home screen.

It is inevitable that there will be sharp contention between conflicting interests. It is to be hoped that shortsightedness and political influence may not unduly retard progress, for in the long run we must inevitably give way to the march of science in television.—Harlan T. Stetson.

BOOK REVIEWS

STRUCTURAL GEOLOGY

Structural Geology. Marland P. Billings. Illustrated. xi + 473 pp. $4.50. 1943. Prentice-Hall.

RELATIVELY few of the divisions of the geological sciences have evolved to the point where quantitative techniques can be utilized commonly. Progress in applied and laboratory geophysics, in seismology, and in the application of mechanics in geology is building an increasingly secure foundation for the field observations and interpretations of the structural geologist. Considerable time, however, is likely to elapse before structural geologists generally will become "precision scientists." Most of them must be content to become acquainted with the concepts and language, and perhaps the spirit of precision technology, and then take off on what literally amounts to flights of controlled imagination.

The book under review unconsciously embodies this concept by beginning with a chapter on "Mechanical Principles" and including others on "Structural Petrology" and "Geophysical Methods". Such materials constitute some of the sharper tools for the analysis of surface structure, which in turn leads to the interpretation of the invisible architecture beneath.

Structural Geology is a straight-forward textbook for advanced students; it is not written nor embellished to tempt a larger patronage. It does not soften the student's approach to the various topics. For example, the discussions of folds and faults begin with chapters on nomenclature and classification and then proceed to the field criteria and examples from the field. To teachers who like to introduce subjects by observation, i.e., illustrative examples, the book under review will prove disconcerting. However, most teachers will welcome the fifty-five pages of well-organized laboratory exercises.

Professor Billings, Mrs. Billings, and many graduate students under their direction and inspiration have contributed substantially to our knowledge of the structurally and petrographically complex tectonics of New Hampshire. In their field work a variety of tools have been utilized and various unusual structural types have been recognized. To some extent this New England influence is manifest in the text. Rather than constituting a personal bias, this influence serves to give the volume unique and valuable quality. The attention paid to igneous rock structures and petrofabrics adds an emphasis which has, in the reviewer's opinion, been passed over too lightly in most general structural geology.

Structural Geology is not a layman's reader; it may well serve as a reference for terminology and principles. It will illustrate to the interested scientist the trends of thought of modern structural geologists and the extent to which application of principles and methods of allied sciences is operative in one of the earth sciences.—MAJOR ALLYN C. SWINNERTON.

THE FLOOR OF THE OCEAN

The Floor of the Ocean, New Light on Old Mysteries. Reginald Aldworth Daly. The Page-Barbour Lectures at the University of Virginia, 1941. Illustrated. x + 177 pp. $2.50. 1942. University of North Carolina Press.

THE "floor" of the ocean by its very inaccessibility has always been obscured by a certain degree of mystery even to students of earth history. From that distinguished geologist, Professor Daly, comes a characteristically forthright synthesis of much data on this subject not generally available heretofore. Professor Daly's latest book is the result of his three lectures delivered at the University of Virginia in 1941. Separated into three chapters, the first describes modern knowledge and theories of what is beneath the floor of the ocean—"the foundations of the deep" and the supposed nature of the earth. The second chapter describes what is known and conjectured about the broader phases of ocean relief, submarine mountains, coral atolls, and volcanic islands. The third chapter deals with the submerged continental shelves and continental slopes and the enigma of the deep submarine canyons and valleys indenting these shelves.

The author's picture of the foundations of

the deep is inferred from geological and geophysical evidence. Long earthquake waves that have passed under many of the oceans indicate a dense rock layer, and this he supposes extends down to a depth of about 50 miles, with possibly "broad veneering patches" of softer rocks. It is concluded that the evidence from studies of gravity, seismology, and geology all point to the existence of a thick layer of exceedingly weak rock that begins at a depth of about 50 miles. This substratum is hot and vitreous according to Daly, and its weakness is due to its yet uncrystallized form. It is assumed that a soft vitreous layer would react to earthquake waves like a solid, but slower stresses would affect it like a viscous liquid.

The results of earthquake studies have supplied a large share of what little is known about the interior of the earth. It should be stated, however, that seismologists do not generally accept Daly's picture of the earth's interior. About the only undisputed discoveries attributed to seismology are the crustal layer, thin or absent over some oceans, and a central core which responds to seismic waves like a liquid. Until many more observations are available from seismographs, especially those located on oceanic islands, a theory that will satisfy all geologic and geophysical ideas on "the foundations of the deep" is not likely to be formulated.

The ordinary reader who wonders about the origin of submarine mountains, oceanic islands, and volcanic activity must be hopelessly confused from the evidence now available. He may gain some satisfaction from the author's own change in view from some of his earlier ideas of volcanic island origin to those announced in the lectures under review. The latter seem to fit better the evidence at hand.

Volcanic islands are attributed to extra masses of rock built up on the "floor" of the ocean from the deep glassy substratum. This molten material is assumed to be world encircling, and issues through vents in the crystallized crust. Although it is reasoned that the strength of the crust is competent to support stably the volcanic island loads, the possibility of horizontal displacements of blocks of the crust of continental dimensions is considered. The regions of the East Indies and West Indies are classed as "mountain chains of Alpine complexity of structure." A convincing demonstration is given that coral atolls and fringing reefs are not upgrowing reefs based on intermittently subsiding volcanic islands; but, "according to better reasoning, the living reefs have grown up from banks and shoals during a slow, late-Glacial and post-Glacial rise of sea level all over the world."

One of the greatest discoveries of the present century in the field covered by the book is the fact that the continental shelves and the continental slopes are so different in physiographic relief. The third chapter comprising almost one-third of the book covers the "continental terraces and submarine valleys." Through the wide use of echo sounding (and more reliable offshore control of position in coastal surveys) submarine valleys of distinctly fluvial characteristics have been found in the continental slopes. So striking is the evidence that these canyons have been excavated by streams to depths of more than 10,000 feet below the present sea level, that any other explanation seems impossible. At the same time, any change in level between land and sea of the order of 10,000 feet in Pleistocene time does not fit existing geologic theories. Daly's original suggestion of density currents to account for these deep valleys in the continental shelves, further developed in these lectures, is the only hypothesis which does not seriously disturb older geologic theories. Briefly the idea is that the storm waves and currents of Pleistocene times acting on the shallow continental shelves so agitated the sediments of the shelves that strong submarine currents of dense mud-laden water rushed down the steep continental slopes and eroded the existing canyons. The author cites especially the experimental evidence obtained by the Netherlands Geologist, P. H. Kuenen, to support this hypothesis. He apparently considers connections with existing land drainage as accidental, which to this reviewer is unacceptable in view of the striking evidence available in such instances as the Congo, Hudson, Mississippi, Columbia, Cagayan, Ganges, Indus, Mindanao, and other major drainage systems of the world. The author mentions the fact that the only thoroughly

sounded areas of the world continental slopes are those of the coastal areas of the United States. It should be added that the coasts of Alaska and the Philippines are in the same category. Even the deep submarine shapes of the so-called volcanic islands used so often in the literature are inferred from such meager data that one cannot consider them conclusive.

The density current hypothesis does not do violence to geologic ideas based upon the concept of relatively permanent sea level; that is, eustatic changes in sea level in Pleistocene or Recent Time not exceeding the order of 300 feet. Although the author suggests that density currents may now be operating in some regions where continental shelves are narrow, no conclusive evidence has been found that the process is in operation anywhere in the world today. Conditions favorable to such bottom currents are supposed, however, to have been effective during Glacial Periods.

The exploration of the continental shelves and slopes and oceanic areas by echo sounding has opened a broad vista into geologic history. When the present destructive interlude is over, we may hope to have a wealth of new data on this subject available to science.

Professor Daly's stimulating lectures will be enjoyed by many readers. His forthright style and lively imagination coupled with his intimate knowledge of earth sciences are well known to American geologists. In this book his capacity for applying "the principle of mutual dependence among the sciences" is thoroughly demonstrated.—PAUL A. SMITH.

HEALTH AND HYGIENE

Health and Hygiene. Lloyd Ackerman. Illustrated. xii + 896 pp. $5.00. 1943. Jacques Cattell.

THE author has produced a well-documented work free from dogma and of value to the student, the lay reader, or the teacher. Each chapter is followed by a truly imposing array of references.

The first chapters are largely historical. They could be improved by a relation of the history, structure, and functions of public health services, both national and local, and a history of medical education in America. Some of the space given to descriptions of the cults could have been so used to better advantage. Otherwise the book is praiseworthy. The literary style is excellent and entertaining, the print is clear, and the references seem to cover the field entirely. Emphasis is laid on mental hygiene, and the treatment is subjective.

Mental diseases are covered as fully as necessary in a work of this sort, and the terms used are reduced to the understanding of the reader who may not have a scientific training. This does not detract from its scientific value; rather it should enhance its value for the student just being introduced to the subject.

The text on vaccines, serums, and vitamins has been stripped down to understandable terms. However, this is so generally true of the whole book that it is superfluous to take up chapters separately.

All in all we have here a scientific treatise on health and hygiene that can be recommended highly.—M. F. OSBORN.

A PRIMER OF ELECTRONICS

A Primer of Electronics. Don P. Caverly. Illustrated. xi + 235 pp. $2.00. 1943. McGraw-Hill.

REALIZATION that knowledge of the general physical principles on which modern electric devices are based had not been made available to even a small fraction of the number of interested people prompted the preparation and publication of this book. Through the book the nontechnical reader can obtain a brief survey of the broad field of electricity, magnetism, and related topics of physical science. Discussion of basic principles is cleverly interspersed with descriptions of their practical application to form an interesting and enlightening review of a broad field.

Electronics is defined in the early part of the book as "that branch of science and technology which relates to the conduction of electricity through gases or in vacuo." The book, however, includes discussions of ultraviolet and infrared, as well as visible, portions of the spectrum. These topics, which are not clearly included by the terms of the definition of electronics, make an interesting addition to the text. At the same time, the book would have been more satisfying, at least to the reviewer, if such discussions had

been omitted or curtailed and an equivalent space used for further explanation of the field of electronics in a more restricted sense. In particular, if the sections on capacitive and inductive reactance could have been expanded to provide a background for an adequate explanation of resonance in radio frequency circuits, the average reader would probably have had his interest stimulated further.

The fundamental principles of vacuum tubes and their simple application in radio circuits are clearly described with the aid of excellent illustrations. Considering the complexities involved, the discussions of television, photograph transmission, frequency modulation, the electron microscope, and other relatively new vacuum tube applications are well done. The average reader, whose background probably includes elementary high school science, will find much of interest and value in this book. It is recommended for such people if they have any feeling of curiosity as to the how and why of the wonders of modern electronics.—GAIL F. MOULTON.

MEDICAL PHYSICS

Medical Physics. Otto Glasser, Editor-in-Chief. xlvi + 1744 pp., 1382 illus. 1944. $18.00. The Year Book Publishers, Inc.

MEDICAL physics is not exactly a new subject. Its beginning extends to the Middle Ages, but the tempo of applications and discoveries has become rapid in the last ten to twenty years. There has grown up a truly stupendous amount of scientific information in this borderline field between physics and medicine. It has, however, suffered from being widely scattered in publications some of which frequently are inaccessible to those most interested.

The text which is the subject of our review is really an encyclopedia in form and scope. The editor and his twenty-two associate editors are to be congratulated that the "small manual" idea of treatment was discarded at this stage of the subject in favor of a more complete and comprehensive treatment. They are further to be congratulated upon enlisting a corps of 245 different specialists, each of whom has prepared articles on one or more subjects. Their 255 articles which comprise the text of this book are arranged alphabetically under the titles. A list of twenty-three subject sections with the number of articles (*Ar.*) in each, the number of different authors (*Au.*), and the name of the associate editor follows:

Subject	*Ar.*	*Au.*	*Associate editor*
Anatomy	23	22	Normand L. Hoerr
Bacteriology	5	6	Otto Rahn
Biometrics	4	4	Charles P. Winsor
Biophysics	41	48	Otto Glasser
Dermatology	4	4	George W. Binkley
Hematology	18	12	Eric Ponder
Medicine	104	113	Russell L. Haden
Neurology	20	25	W. James Gardner
Nuclear physics	11	11	Robley D. Evans
Ophthalmology	7	8	A. D. Ruedemann
Optics	15	15	W. B. Rayton
Orthopedics	12	12	James A. Dickson
Otolaryngology	9	8	Paul M. Moore
Pathology	31	36	Harry Goldblatt
Pediatrics	1	1	Norman C. Wetzel
Photography	16	16	Leo C. Massopust
Physical chemistry	27	28	F. M. Whitacre
Physical therapy	29	35	Walter J. Zeiter
Physics (methods)	58	66	John G. Albright
Physiology	101	111	Harold D. Green
Radiology	67	72	Harry Hauser
Surgery	40	48	Frederick R. Mautz
Urology	15	17	Charles C. Higgins

The text is printed in double columns, and the excellent illustrations are numbered separately for each article. The working formulae and tabular material are noteworthy features of the book. A suggested bibliography in brief form is appended to virtually all of the articles.

The extensive subject index, which comprises 44 pages of three columns to the page, is intended to unify this book. The analysis is detailed and appears to be entirely adequate. The subject index is followed by a name index of 16 pages, four columns to the page.

The material covered ranges widely and embraces the whole meeting ground of physics, medicine, chemistry, biology, engineering, and other sciences. Under nuclear physics, for example, occur such articles as descriptions of betatrons, cyclotrons, Geiger counters, and a discussion of tracer techniques. Under medicine occur such topics as specific gravity and solids of blood, effect of heat and cold, exercise and posture, motor functions, and fever therapy. Then there are splendid discussions of such subjects as chlorophyll,

bio-electricity and cinematography. Some of the subjects seem to have been covered in the fullest way, as for example the exhaustive treatise on photometry, covering 33 pages with $5\frac{1}{2}$ columns of bibliography. No effort seems to have been spared to get the best of authorities in the particular fields. Zworykin, for example, writes on the electron microscope, Wollan on cosmic rays, Trump on supervoltage generators, Rashevsky on mathematical biophysics, to mention only a few names immediately familiar to physicists.

It would require an entire faculty of a university in which such schools or departments as physics, chemistry, mathematics, biology, physiology, and medicine were particularly strong to give a critical evaluation of the discussions. It appears to the reviewers to constitute a necessary text and reference work for all specialists either within or on the edge of this field. It will be useful for consultation by students and teachers particularly as a reference work for concise, up-to-date discussions in this field. The reviewers are impressed with its apparent usefulness also to practicing physicians and experimental medical scientists.

The editor speaks of the book as being designed to serve as a *textbook* and as a *working instrument.* Actually it is doubtful if it will serve very well as a textbook, which in this field is long overdue. What is needed, however, is a book of about one-fifth the size of this one, and leaning heavily on it for information and inspiration. This book will no doubt hasten the advent of such a text now that the material is accessible. The encyclopedic arrangement is indicative of the main purpose of the book; namely, to serve as a basic reference work in libraries and hospitals and for every physician and scientist who works in the borderland between the pure sciences and medicine.

The publishers are to be commended for undertaking the expensive task of publishing so comprehensive a work, but they have succeeded well. The reviewers find it remarkably free from typographical errors.

It may be expected that this work will result in increased emphasis on this subject in schools of both physical science and medicine. It is likely to stimulate research in this field. It is difficult to see how the conscientious researcher can afford to be without the information here assembled in ready form.—Roger C. Smith (Biology) and M. H. Trytten (Physics).

PRINCIPLES OF BEHAVIOR

Principles of Behavior. Clark L. Hull. x + 422 pp. $4.00. 1943. Appleton-Century.

This book vigorously denies that any branch of the social sciences is inaccessible to objective mathematical inquiry. The first two chapters are devoted to a luminous exposition of the nature of scientific and objective behavior theory. In these lucid pages Dr. Hull declares that ". . . natural science theory is aggressive towards the problems of nature, and it uses logic as a tool primarily for mediating to the scientist himself a more perfect understanding of natural processes" (p. 8). This is a far cry from the baby-with-bathwater objectivism of the Watsonian era. Science ". . . has postulates but no axioms in the Euclidian sense . . . scientific theory reaches belief in its postulates to a considerable extent through direct or observational evidence of the soundness of its theorems" (p. 9). Hull rejects "emergentism" as a pseudo-remedy and a doctrine of despair, maintaining that supposedly impossible derivations with regard to goal or purposive behavior are actually possible by reference to stimuli and movement.

The intricacy of such concepts as intelligence, insight, goals, intents, strivings, and value is fully realized by the author, who nevertheless states ". . . the relative backwardness of the behavior sciences is due not so much to their inherent complexity as to the difficulty of maintaining a consistent and rigorous objectivism" (p. 28).

After this prologue Hull proceeds to derive sixteen basic molar postulates and five major corollaries from a detailed examination of numerous experimental studies in the field of animal behavior. The complicated equations which support these postulates are relegated to terminal notes after each chapter. A comprehensive glossary of terms is also included.

The author offers a theory of primary motivation which states that ". . . the potentiality of response evocation is the product of a function of drive intensity multiplied by a

function of habit strength." Drive itself is a logical construct ". . . since it cannot be observed directly any more than can effective habit strength" (p. 390). Drive stimuli become integrally associated with the habit involved through conditioning to the reaction which is associated with reduction of a need.

The concept of "behavioral oscillation" is introduced to account for the failure of effective reaction potential to function fully in the evocation of action. Oscillation, or the variability of response from moment to moment in the presence of a constant stimulus situation seems to distribute itself in the form of a Gaussian curve. This little-understood physiological process ". . . is in a large measure responsible for the fact that the social sciences must pool many observations before ordinary empirical laws become manifest. Thus natural laws in the social sciences must always be based on statistical indices of one kind or another" (p. 393). Is this not also true of the physical sciences? Behavioral oscillation ". . . has doubtless appreciably retarded the development of the behavior sciences" (p. 393). Apparently complexity, after all, must share honors with lack of objectivity in retarding the growth of these sciences.

Hull's prophetic credo hurls a ringing defiance against the decadent doctrines of Emergentism, Intuitionism, and similar defeatist theories. "Progress in this new era will consist in the laborious writing, one by one, of hundreds of equations; in the experimental determination, one by one, of hundreds of empirical constants contained in the equations . . . in the ruthless discard or revision of once promising principles or concepts which have failed wholly or in part to meet the test of empirical validation."

This book is more than a technical discussion and derivation of basic principles. It represents a bold and imaginative affirmation of faith in scientific method when the flame of that faith is flickering in the winds of the world holocaust. For intellectual inspiration and inspiration in seminars on scientific method and psychology it will have few equals.—Fred Brown.

AMERICAN PSYCHIATRY

One Hundred Years of American Psychiatry. Published for the American Psychiatric Association. Illustrated. xxiv + 649 pp. $6.00. 1944. Columbia University Press.

This handsomely produced volume marks the centennial of the American Psychiatric Association, the oldest national medical organization in America. Thirteen contributors, between them, deal with such subjects as the development of psychiatry from colonial days to the foundation of the Association, psychiatry in Europe at the middle of the 19th century, the founding and founders of the Association, the history of American mental hospitals, psychiatric research in America, American psychiatric literature, the history of psychiatric therapies, the history of mental hygiene, military psychiatry in the Civil War and first and second World Wars, psychology in relation to psychiatry, American psychiatry as a specialty, legal aspects of psychiatry, and psychiatry and anthropology. These papers are most attractively written, and contain a remarkable amount of useful information interestingly presented. The book is well illustrated and contains an excellent index.

American psychiatry may well be proud of its hundred years of achievement, and in keeping with the high standards of that achievement the present volume forms a fitting centennial celebration of that event. The reviewer enjoyed the privilege of attending the centenary meetings of the American Psychiatric Association held in Philadelphia in May, 1944, and he can testify not only to the success of that meeting but also to the glowing health of psychiatry as a branch of medicine.—M. F. Ashley Montagu.

COMMENTS AND CRITICISMS

Fair and Warmer

Weather forecasting may be a science in the United States, but it's still an art, romantic and elusive in Colombia. Doubtless the air lines even there manage things differently, but the daily paragraphs headed "Meteorological Data" that appear in *El Tiempo,* the Times of Bogotá, Colombia, are literary gems, polished, cultured, urbane—and vague.

"Increasing cloudiness and slightly warmer today and tonight. Tomorrow partly cloudy and warmer, with a thundershower in the afternoon." Never has such a crass, utilitarian forecast appeared in the leisurely pages of *El Tiempo.* Where would be the poetry, the erudite reference, the literary style? Factualism is for the gringos, say the Latin-Americans; we'll take literature.

"It has been reasonably said," writes Don Guillermo Bonitto in one of his paragraphs of meteorological data in *El Tiempo,* "that new things may be found in old books. Indeed, since the colonial epoch (according to incomplete records), the climate of Bogotá has been characterized by high indices of humidity during cycles or periods fluctuating between five and six months in length; in such periods even the months of July and August have been rainy and very cold as at present, a condition that will very probably continue until the end of the month."

Don Guillermo, the writer of the daily paragraphs, is obviously a gentleman who takes the larger view. Not for him the mere twenty-four hour forecast, the precise anticipation of maximum and minimum temperatures, the bare details of wind direction and precipitation. Not for him the paraphernalia of isobars and humidity symbols, barbed arrows and austausch coefficients. Weather forecasting for Don Guillermo is a branch of literature.

Once he began his daily paragraph with unaccustomed precision: "Probable condition of the atmosphere: strong sunshine followed by rain." He quickly repented, however. The next sentence indicated his difficulty: "The laws of physics and mathematics," he wrote, "so wisely combined by the Supreme Divinity, stand in contradiction to the limited knowledge which human science has been able to acquire concerning the relationship existing between them." A becoming humility, no doubt, but not very helpful to the picnicker.

Don Guillermo's work as a weather forecaster evidently keeps him constantly aware of the contrast between human science and divine wisdom. The intermingling of human and divine, he points out on another occasion, is reflected in the combination of science and religion that erected the temples of the Assyrians and Chaldeans as well as those of the Muiscas and Sugamuxis right in Colombia. Full of mystery as those solid, tangible structures are, who are we moderns that we pretend to understand, much less foretell, the vagaries of the elusive, intangible atmosphere?

But Don Guillermo is at his best when he is most historical. "These epochs of abundant rain," he writes (it rains almost all the time in Bogotá), "agree with the records left us by some of the Conquistadors, records later studied by Humboldt, the marvelous Caldas, Toaldo, and other authors who labored in the field of meteorology, a science very useful for progress, but still in its cradle here in the tropics."

With considerable justice Don Guillermo is consistently pessimistic about the weather in Bogotá. Rank amateur though I am, I can testify that the temperature hovers around fifty degrees Fahrenheit the year round and that it rains continually, now drizzling, now pouring. Old residents sadly assert that six totally clear days in any one year would establish a record. Thus, after one spell of clear weather, Don Guillermo reminded his readers of the inevitable. "According to careful studies," he wrote, "the three days of splendid sunshine now enjoyed in Bogotá will be succeeded by our customary weather within another day."

Sometimes Don Guillermo takes time out to reply to his correspondents. "Some kind readers of these essays," he writes, "have asked the author to write at greater length. Gladly would he comply if he were a writer; but, aside from his complete lack of such talent, he adheres to the doctrine of expressing ideas in the most concise, brief, and concrete form possible, even though he make mistakes, and he does with considerable frequency."—James Paul Stoakes, Marshall College, Huntington, W. Va.

Prometheus Bound

In the March, 1944, issue of The Scientific Monthly, which has just reached this distant spot in New Guinea, there is an article by Dr. Pei-Sung Tang entitled "Helios and Prometheus: A Philosophy of Agriculture." Three statements therein are believed to be so unscientific in character that they should be discussed further, lest readers unfamiliar with the progress of science in certain fields give undue weight to the fact that the assertions appear in The Scientific Monthly.

The first of the three is found in the fourth paragraph, where the author says, "He [man] is not only constantly subjected to the Malthusian struggle between himself and his fellow men; . . ." This apparent indorsement of the so-called "Malthusian Theory" will be surprising to every scientist who has troubled to read Malthus' exposition of this notion,

because a less scientific combination of geometrical and arithmetical progressions, unsupported by anything that a scientist would consider relevant data, would be difficult to imagine. The widely used but little read "Essay on Population" would hardly deceive a college sophomore today, and THE SCIENTIFIC MONTHLY would, I feel certain, immediately reject a manuscript so obviously fallacious; unless, indeed, you chose to publish it as an illustration of the absurd results sometimes obtained by failure to apply the scientific method.

It is hardly possible that those of your readers who are active in applying the scientific method will not immediately see the absurdities involved in Malthus' "theory." For those who would prefer to read a scientific analysis of the "theory," I suggest reference to the works of a writer whom John Dewey has called one of the few great thinkers who have left a written record of their work since the dawn of recorded history. In Book II of "Progress and Poverty," Henry George subjected the "Malthusian Theory" to a scientific analysis that, were it not for the perennial rebirth of great delusions, would have long since disposed of the "theory."

The second point deserving further consideration is Dr. Tang's assertion, "Until the time when he [man] can reproduce this apparently simple process of photosynthesis in his laboratory, independently of the green plant, man cannot claim to be free from the vestiges of his ancestral sun and fire worship." It hardly seems possible that Dr. Tang is here using words in a scientific manner, that is, for symbolic rather than poetical purposes. Possibly a poor translation has occurred. In any event, there is no apparent reason why primitive superstitions should continue, even in part, until man has solved any particular scientific problem. Probably most scientists would claim to be free of any vestiges of "ancestral sun and fire worship," and I think their claims would be justified.

The third point deserving further consideration is found in Dr. Tang's statement, "So long as the population of the world does not decrease, so long as the present practice of agriculture cannot be expected to give significant increase in crop yield, the competition between man, animal, and plant for land area will forever be a barrier to providing animal products for human consumption." The implication of this statement seems to be that the *future* practice of agriculture cannot be expected to give a marked increase in crop yield. (Obviously, the "present practice" can be nothing but the "present practice" in any event; only the future practice has any chance of increasing the crop yield. I am assuming that Dr. Tang intended to say something of significance.)

Now, one of the more interesting developments of recent decades has been the very great increases in crop yields that have resulted from crop rotation, more effective fertilization, and particularly from the use of more carefully selected seed resulting from scientific cross-breeding of various plants. Not being an expert in the latter field, I may have chosen the wrong technical phrase to describe the procedure, but most readers will no doubt understand my reference. In view of these developments, and in view of the primitive and inefficient farming procedures still followed by most of the farming population of the world, I believe that the future practices of agriculture can be expected to give significant increases in crop yields.

It may well be that improved practices will not be readily adopted in such countries as India and China, but this will not be because improved practices "cannot be expected to give significant increase in crop yield." It will be for the simple reason that any significant increase in crop yield would be of no benefit whatsoever to the tax burdened, rent racked, and bandit ridden "share croppers" of India and China. They are now regularly stripped of all but that needed to keep life in their bodies, and, as they know all too well to their sorrow, a more bounteous harvest but increases the greed of their extortioners. All incentive for adopting improved practices has been taken from them, to such an extent that when crops are even slightly subnormal thousands starve in order that the tax gatherers, and other "bandits" may continue to live in the style to which they have become accustomed.

There is no doubt that modern methods and utilization of land not now producing food (including such vast areas as the valley of the Amazon, now being "pioneered" as our middle west was a century ago, and those large and tremendously fertile areas of which New Guinea is an example) could result in multiplying several times over the present crop and animal products of agriculture. It is not to the niggardliness of nature nor to the backwardness of scientific progress in agriculture that we should look for explanation of the undernourishment described by Dr. Tang.—COLONEL E. C. HARWOOD, C.E.

Hybrid

Reference is made to a paper entitled "The Forbidden Land" in the May, 1944, issue of THE SCIENTIFIC MONTHLY. In Figure 10 on page 355 there is a picture of an animal described as a yak. This is apparently not a yak, but a hybrid between domestic cattle and the yak, which the Chinese refer to as a *pian niu*.—RALPH W. PHILLIPS.

Better Late . . .

The photograph of James McKeen Cattell appearing in THE SCIENTIFIC MONTHLY of April, 1944, is derived from the *Journal of Consulting Psychology* (copyright 1937). Ex post facto acknowledgment is hereby made.—EDS.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1944

ELECTRONIC MICROSCOPY

By V. K. ZWORYKIN and JAMES HILLIER

DURING the latter half of the last century Abbe demonstrated the diffraction theory of microscopic vision and in so doing discovered the limitations imposed on the resolving power of any microscope by the wave nature of the radiation used. Mathematically he was able to show that no matter how perfect the lens system of a microscope it cannot produce resolved images of structures which are separated by less than one-half the wave-length of the light used. This naturally led to the use of light of shorter and shorter wave-lengths in the ordinary optical microscope. Finally by the use of ultraviolet light the resolving power of the optical microscope was increased some two and a half times. It was not possible, however, to extend the resolving power indefinitely by this method because of the apparently fundamental lack of suitable lenses for extremely short wave-lengths. The highly perfected optical microscopes of the present have almost attained the theoretical limits indicated by Abbe. Using visible light they can resolve structures separated by 250 millimicrons (0.00001 inch), whereas with ultraviolet light they can resolve as low as 100 millimicrons.

In discussing the limiting resolving power of a microscope it is usual to state it as a "maximum useful magnification." Unfortunately, there has been considerable confusion regarding the use of this term because the magnification of any microscope can be adjusted by the use of proper lenses to *any* value that the user desires. The term "maximum useful magnification" refers to that magnification at which the finest details resolved by the lens system become just visible to the unaided eye. Thus if we assume that the human eye cannot resolve less than 0.2 millimeters, we find that it requires a magnification of 800 diameters to make visible to that eye the details resolved by a microscope using visible light. On the same basis the maximum useful magnification which can be obtained with a microscope using ultraviolet light is around 2000 diameters.

For many years the problem of improving the resolving power of the microscope appeared to be incapable of solution. The search, however, had been restricted almost entirely to the realm of optics, whereas actually the solution lay in an entirely different field—electronics.

THE ELECTRON MICROSCOPE

A little over fifteen years ago it was found that the path of electrons in electric and magnetic fields could be described in terms which are analytically equivalent to those of optics. By means of this electron optical equivalence it was shown that axially symmetric electric or magnetic fields had the properties of optical lenses, and, consequently, that it is possible to form electron images in the same way that light images can be formed. At about the same time the discovery had been made that any material particle in motion had associated with it a characteristic wave-length. For electrons (accelerated by 60 kilovolts) this wave-length was found to be very small—around 0.05 angstrom unit or only about 1/100,000 that of visible light. This meant that suitably designed electronic systems employing these high-speed electrons should be capable of extremely high resolving power.

These two concepts led directly and logically to the idea of an electron microscope

based on principles similar to those used in an optical microscope, but in which the various components are replaced by their electron optical equivalent (Fig. 1). Such an instrument employs condenser, objective, and projection lenses performing the same functions as the corresponding elements in the light microscope, but the lenses, instead of being made of glass, are formed by axially symmetric electric or magnetic fields. During the past ten years, instruments of this type have been investigated in detail in various parts of the world. As a result, the electron microscope has been developed to a point where it is capable of a useful magnification nearly two orders of magnitude greater than the ordinary light microscope. Until recently the development has been in the hands of physicists, and the instruments built were designed almost entirely for the purpose of studying the microscope itself. However, the electron microscope has progressed beyond this stage and has now become a research tool of great value. Ever-growing numbers of commercially built electron microscopes are being put into use in all types of research organizations, and already many important, and even some spectacular, results have been achieved.

All electron microscopes which have been built to give the highest possible resolving power have followed a more or less conventional pattern. They consist of three essential components: the electron microscope proper, the power supply, and the vacuum system. Figure 2 (left) is a photograph of the RCA Type B electron microscope in which all three components are combined into a single unit. Figure 2 (right) is a sectional diagram indicating details of construction more clearly. The electrons used in the imaging process are supplied from the electron gun (A) including a thermionic cathode which is maintained at 60 kilovolts negative with respect to ground and a final anode at ground potential. Between the two are

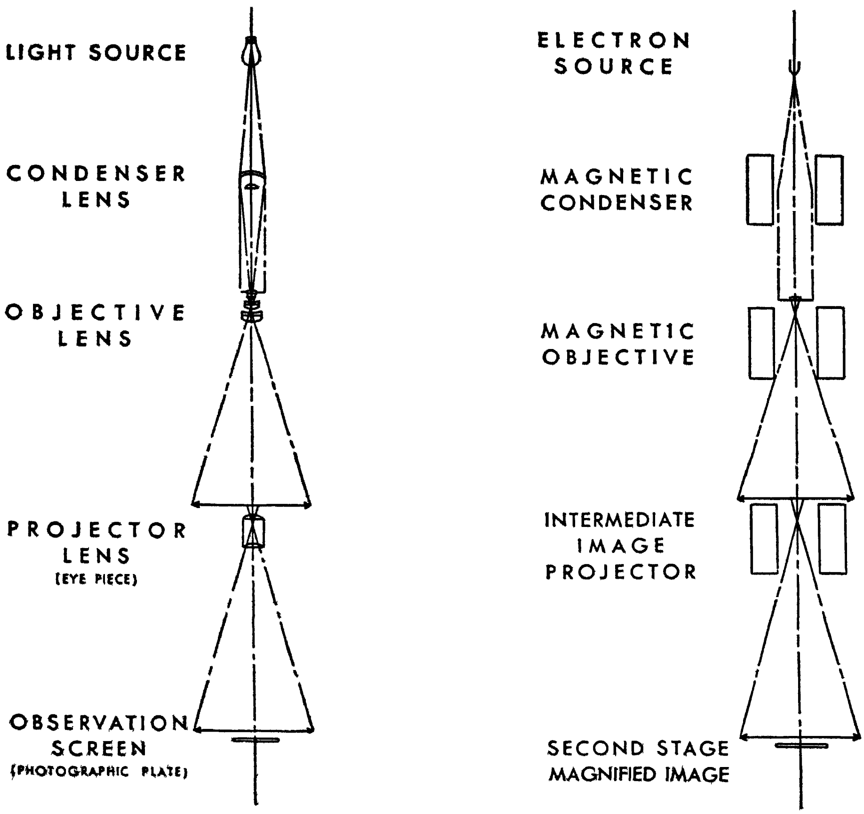


FIG. 1. SIMILARITY BETWEEN A LIGHT MICROSCOPE AND AN ELECTRON MICROSCOPE

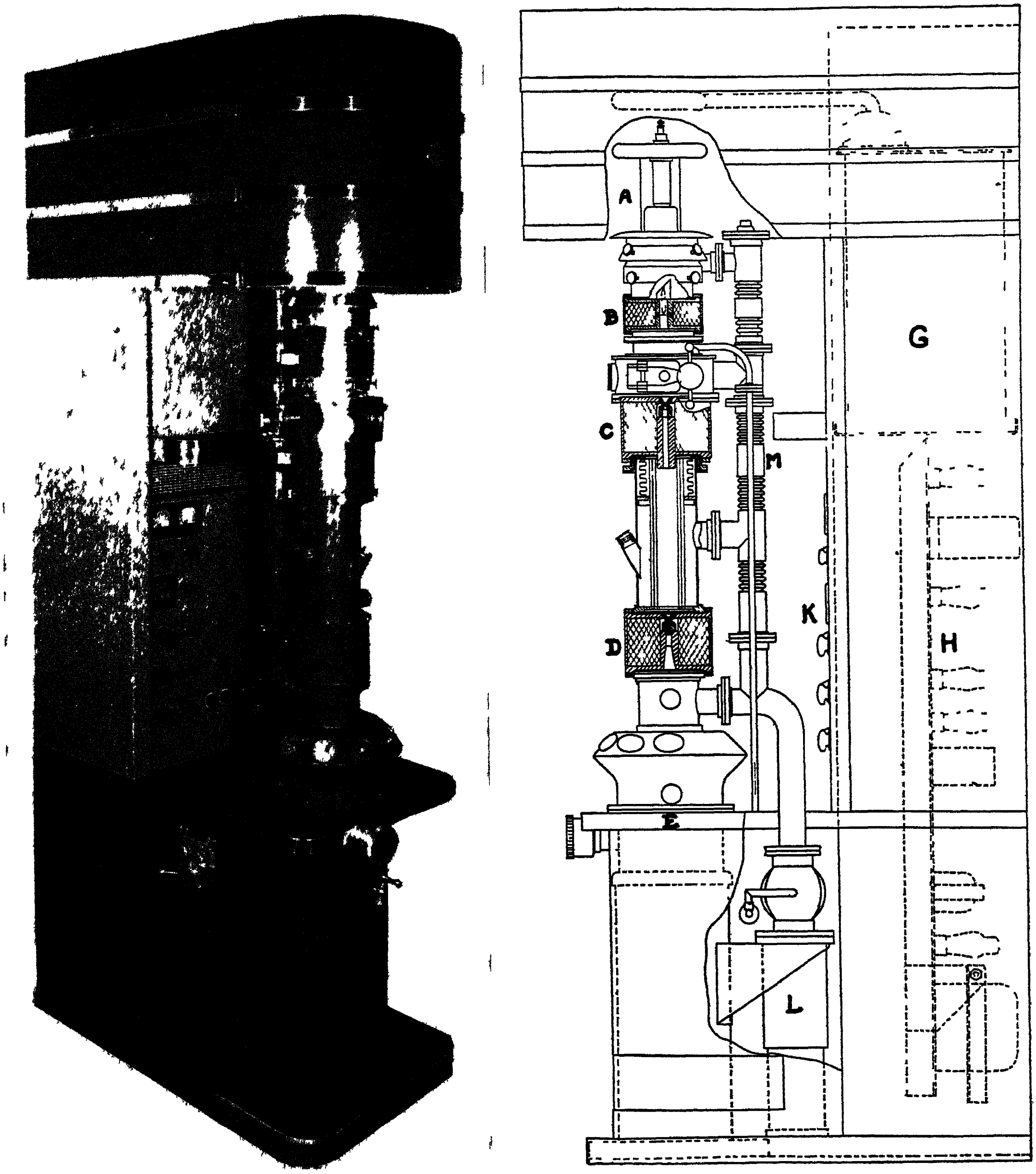


FIG. 2. LEFT, AN RCA ELECTRON MICROSCOPE; RIGHT, CROSS SECTION OF SAME

disposed the electrodes required for controlling the electron paths. The electrons leaving the gun have their full velocity, corresponding to 60 kilovolts.

The condenser lens (B), which consists of an iron-clad coil with polepieces shaped to give the required magnetic field, causes the electrons to converge upon the specimen held a few centimeters below it. The condenser, like the condenser lens of a light microscope, can be used to control the angular aperture and hence the intensity of the illumination at the specimen.

After passing through the specimen, the electrons enter the objective lens (C). This lens deflects the electrons leaving the specimen in such a way as to focus them into a magnified intermediate image of the specimen. This image is formed directly above the projection lens (D). The objective, like

the condenser, is an iron-clad coil, but the polepieces are, of course, different in design to meet the requirements of this element.

The final image is formed from that portion of the intermediate image which passes through the projection lens (D) and is reimaged in the plane of the observing screen or photographic plate at (E). The observing screen is coated with a fluorescent material producing a visible image by means of which the operator can focus the instrument and can adjust the specimen to obtain an appropriate field of view. The fluorescent screen is hinged so that it serves as a shutter to the photographic chamber immediately below it. The photographic record is made by allowing the electronic image to fall directly on the sensitive emulsion of the photographic plate.

The magnification of the objective lens is usually around 100×, though by changing the position of the specimen and the strength of the lens it can be adjusted to lie anywhere between 50× and 100×. The magnification produced by the projection lens can be varied from 20× to 300× so that the total magnification of the instrument can be controlled over the range 1000× to 30,000×. By properly modifying the polepieces of the objective and projection lenses, the instrumental magnification can be varied from as low as 200× to as high as 100,000×. However, as mentioned earlier, the magnification used has little significance as a measure of performance of the instrument. This type of electron microscope is capable of a resolving power of as low as 2.0 millimicrons, which corresponds to a maximum useful magnification of around 10,000×. In practice, however, it is found that *instrumental* magnifications of this magnitude are both unnecessary and undesirable. Instead, magnifications of the order of 10,000× are used, and the images are recorded on fine grain photographic emulsions which permit subsequent optical magnifications of 10×. In this way the full useful magnification of the electron microscope can be attained with a minimum exposure, minimum requirements of the power supplies, and maximum field of view.

All the power supplies (G) and (H) and electrical controls (K) necessary for the operation of the electron microscope are contained in the cabinet at the rear of the microscope column. Since the power of a magnetic lens depends on the current through the lens coil and on the velocity of the electrons being focused, it is obvious that sharp photographic records would not be possible if any of these quantities varied during the exposure time. Therefore, it is essential that all the voltages and currents be extremely stable. To accomplish this, special electronically stabilized power supplies were developed in which the lens currents and the high voltage supply are held constant to within 0.005 per cent. To stabilize the high voltage, a sample of the voltage is compared with that of a standard battery. Any slight differences which may occur between the sample and the standard are amplified and used to control and correct the main system. In the case of the coil currents the method is the same except that the voltage drop occurring across a standard resistor through which the coil current is flowing is used as the sample.

Electrons will not travel freely through air; hence the entire electron optical path of the microscope must be under vacuum; that is, at a pressure of about 0.0001 millimeter of mercury. Since an electron microscope is a rather complicated instrument, having a number of parts which must be moved inside the vacuum, and requires facilities for quickly removing and introducing specimens and photographic materials, as well as for ease in disassembling and servicing, a number of innovations in vacuum practice have been introduced. A number of the joints, such as those between the electron lenses and the microscope chambers, are made demountable. Such joints are sealed by means of synthetic rubber gaskets and are arranged in such a way that the alignment is maintained by metal-to-metal contacts rather than by metal-to-plastic contacts. At certain points in the microscope, parts must be movable with respect to one another in order to permit alignment. Such points are joined by flexible metal bellows so the adjustments may be made while the microscope is under vacuum and in operation. If, in an instrument of this size, it were necessary to repump the entire microscope every time a specimen or photographic plate is changed, it would greatly curtail the speed of operation. Consequently, air locks are provided which per-

mit making these changes without breaking the main vacuum.

The main microscope chamber is pumped through the large manifold (M) by a fast oil diffusion pump (L). This pump is backed by a mechanical forepump. A second mechanical pump is used to exhaust the two air lock chambers.

While the electron optical design of an electron microscope is quite analogous to the optical design of a light microscope and while the images of one object formed in the two instruments are *geometrically* identical, there are fundamental differences in the mechanism of the image formation in the two instruments. They correspond in that the differences in intensity, which constitute the image in either case, are the result of differences in the nature and amount of interaction between the incident beam and the points of the specimen. However, in the case of the light microscope the differences in interaction between various points of the specimen and the illumination are due to differences in index of refraction, in selective absorption, in scattering power for the light used, in the conditions of reflection from variously orientated surfaces, and in the size of smaller particles; whereas in the case of the electron

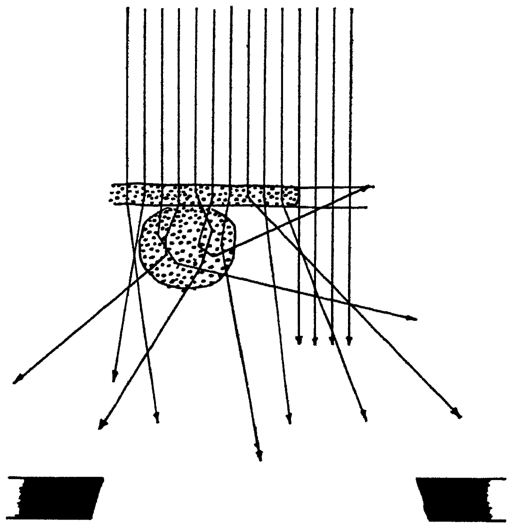


FIG. 4. SCATTERING OF ELECTRONS
THE THICKER AND DENSER PARTS OF THE SPECIMEN DEFLECT ELECTRONS AWAY FROM THE LENS APERTURE.

microscope they are due to differences in the scattering power, in the interference conditions for crystalline particles, and in the size of the particles.

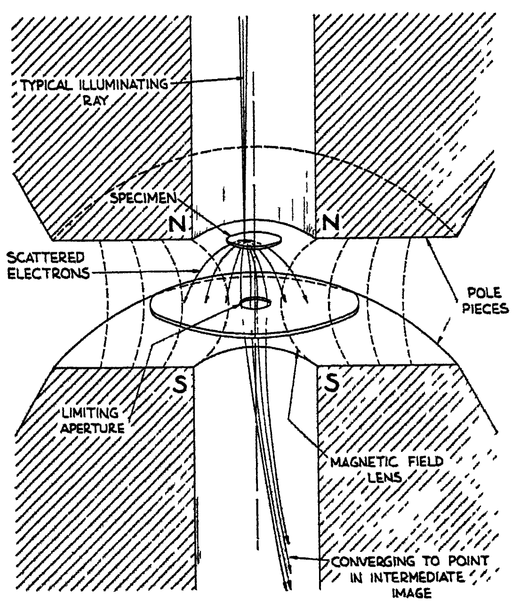


FIG. 3. ELECTROMAGNETIC OBJECTIVE
THE ELECTRON PATHS ARE REPRESENTED BY SOLID, ARROWED LINES; MAGNETIC FIELD LINES ARE DOTTED.

Figure 3 shows diagrammatically the trajectories of the electrons in a fine pencil arriving at the specimen and passing through the objective. It is shown that any point of the specimen is illuminated by a fine beam of electrons, all of which are contained in a cone of extremely narrow half-angle. Of the electrons passing through the specimen, only those whose paths make relatively small angles with the axis of the system will pass through the objective aperture and reach the intermediate image. Thus, the intensity of any point of the image will depend on the number of electrons which left the corresponding point of the object in a direction enabling them to pass through the objective. This will, in turn, depend on the scattering power and hence the mass density of the specimen point. This is illustrated in Figure 4 where the cross section of the specimen has been greatly enlarged and some of the probable electron paths have been drawn in. It can be clearly seen how areas of greater thickness or greater density increase the scattering power of the object and hence decrease the intensity of the corresponding image points.

Associated Developments

The electron microscope by itself provides exact information regarding the size, shape, and structure of finely divided matter, but little more. To make full use of its powers it is necessary to use it in conjunction with other equipment or experiments, some of which can be combined with the instrument itself.

Stereomicrographs. An ordinary micrograph, whether obtained with an electron microscope or with a light microscope, represents the object in two dimensions only; in effect, it shows a projection of the object on a plane normal to the instrument axis. The characteristics of the object in the third dimension (in a direction along the axis) can be inferred only indirectly. On the other hand, if the object is viewed from a different angle by each eye, the brain fuses the two images; the result is a perception of the object in its three dimensions. Thus if two micrographs of the same object, inclined by a small angle (e.g., 4°) in two opposite directions to the axis of the objective, are viewed in an ordinary stereoscope, a three-dimensional representation is obtained. In the case of high-power light microscopes this procedure is impractical since their depth of focus is so small that the required inclination of the object would blur the image, except in a very narrow range. The electron microscope, on the other hand, has extraordinarily great depth of focus and is ideally adapted for this purpose. To obtain the two stereo-images the object screen is inserted at the bottom of the special object holder. It is placed in the object chamber, and a first exposure is made. Then the holder is taken out and the central inclined portion is rotated through 180° about *its* axis. After the holder, also rotated by 180°, has been reinserted into the object chamber, the second exposure is made; except for a reversal of its inclination with respect to the optic axis, the object occupies now the same position relative to the objective as in the first exposure. The impression of depth in the resulting stereopictures is striking. Figure 5 is a stereomicrograph of zinc oxide smoke.

Electron diffraction adapter. Of even greater value, especially for the chemist, is an adapter which converts the electron micro-

FIG. 5. STEREOSCOPIC ELECTRON MICROGRAPH OF ZINC OXIDE SMOKE

WITH PERSISTENT PRACTICE THE TWO PHOTOGRAPHS CAN BE VIEWED AS ONE WITHOUT A STEREOSCOPE IF A CARD IS HELD BETWEEN THEM SO THAT EACH EYE SEES ONLY ITS RESPECTIVE IMAGE. ENLARGED ABOUT 13,350 ×.

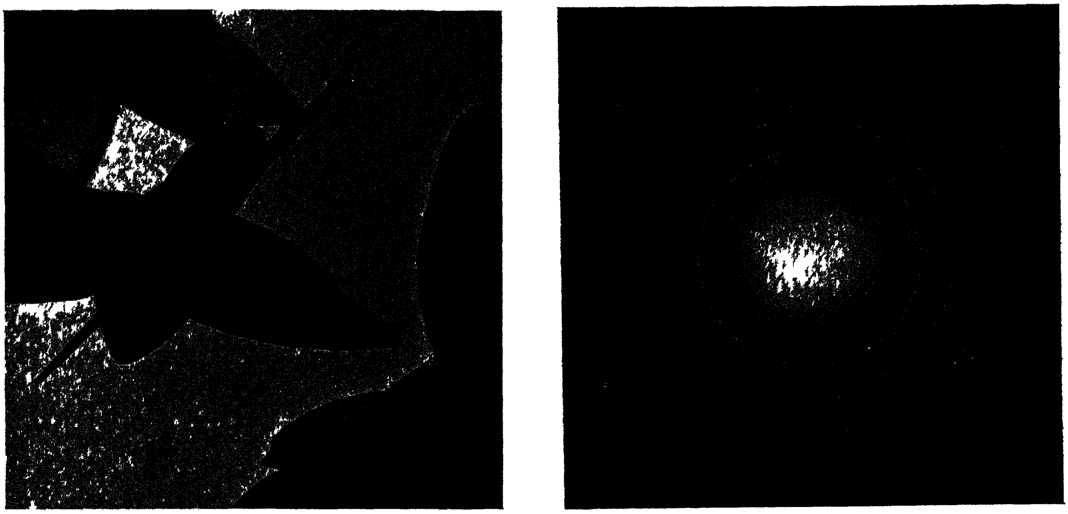


FIG. 6. A CHEMICAL COMPOUND AND ITS DEFLECTION OF ELECTRONS
Left, ELECTRON MICROGRAPH OF MONOHYDRATED ALUMINUM OXIDE; *right,* ITS ELECTRON DIFFRACTION PATTERN.

scope into a high-precision electron diffraction camera for the determination of the crystalline structures of materials. This adapter replaces the usual projector lens by a unit containing, in addition to a magnetic projector lens, a specimen holder and a special focusing lens for the diffraction camera. When the electron microscope is used as a diffraction camera, the specimen is removed from the object chamber and inserted above the special focusing lens. The objective forms an exceedingly fine point image of the source, so that any part of the specimen is struck by electrons coming from one direction only. The projector lens is rendered inoperative. At the object the incident electrons are deflected or "diffracted" through angles which are characteristic of the relative separations and orientations of the atoms in the crystal lattice of the specimen. The focusing lens serves to concentrate all electrons deflected through a given angle and in a given direction at the same point of the plate.

The specimen holder of the camera is designed for a quick and convenient transfer of a specimen from the microscope object chamber to the camera, so that the diffraction pattern, giving information regarding the crystalline structure of the materials, may be compared directly with the micrograph of the same substance. It is also convenient for the study of any other small specimens, whether transparent or opaque to electrons; in the latter case it must be so oriented that the electron beam just grazes the surface. Provision is made both for moving the specimen back and forth and for rotating it after it has been introduced into the vacuum.

If the substance studied consists of small crystalline particles oriented in random fashion, the deflection of the ray through a given angle may take place with equal probability in any azimuth, so that the diffraction points on the plate arrange themselves in circular rings about the axis, giving rise to a so-called Debye-Scherrer diagram. The spacings and relative orientation of neighboring atoms in the crystal lattice may be determined from the diameters of the rings. This can be done to within 0.3 per cent. Figure 6 (right) shows the electron diffraction pattern which corresponds to the monohydrated aluminum oxide shown in Figure 6 (left).

A 300-kilovolt electron microscope. It has already been mentioned that the scattering and absorption of electrons by matter is such that only very thin specimens can be examined successfully with the standard electron microscope, which has an accelerating voltage of 60 kilovolts. In many fields of investigation this represents no particular limitation. Particularly in the study of very fine structures and dispersed material, where

FIG. 7. AN EXPERIMENTAL SCANNING ELECTRON MICROSCOPE

the thicknesses are comparable to the widths of the individual entities, the substances are adequately transparent. Not infrequently the operation at voltages below 60 kilovolts

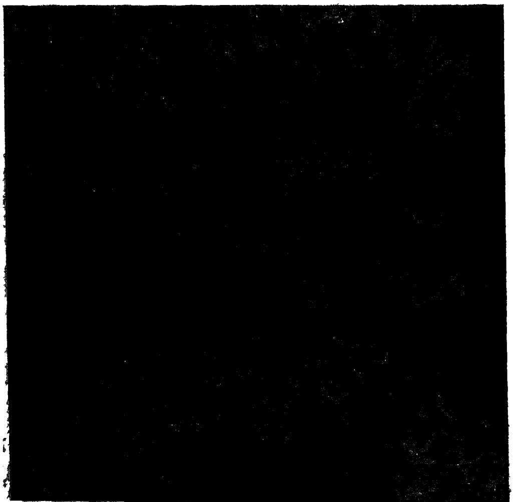


FIG. 8. MICROGRAPHED BY SCANNING EMBEDDED IN BAKELITE, PARTICLES OF CARBONYL IRON WERE SCANNED. MAGNIFICATION ABOUT 1,290 ×.

presents a definite advantage; greater image contrasts are possible and hence easier recognition of very thin structures. However, in a number of other cases, such as the study of the inner structure of large bacteria and the study of cut sections in histological research, the thickness of the specimen is such that the field appears completely opaque or that interesting structures appear only with inadequate definition. Under such circumstances the use of electrons of greater velocity and hence of greater penetration becomes profitable.

With this in mind, an electron microscope operating with electrons accelerated through potential differences up to 300 kilovolts was constructed. The principal modification of the instrument rests in the high-voltage equipment, which is housed in a large separate oil tank, and in the design of the "electron gun," in which the electrons acquire their high velocity.

With this instrument some of the structures which appear opaque in lower voltage instruments can be examined.

Scanning electron microscope. It has already been indicated that electron microscope specimens must be sufficiently thin if satisfactory images are to be obtained. In the case of metallurgical samples this was not possible, though the need for the high resolution of the electron microscope was quite evident. This led to the development of an instrument designed specifically for examining the surface of opaque specimens. The new instrument is known as the scanning electron microscope and differs basically both from the standard electron microscope and the conventional light microscope.

In place of forming the complete image simultaneously, the intensity of a single minute picture element, corresponding to a half-tone dot in the printed reproduction of a photograph, is recorded at any one time; as in electric picture transmission and television, the final picture is built up from a great number of such elements of different intensity.

In brief, a succession of electrostatic lenses forms a greatly reduced image of an electron source on the object; the diameter of this "electron spot" is less than 25 millimicrons, corresponding to a single picture element of the final image. The secondary electrons given off by the object where struck by the electron beam measure the relative "brightness" of that particular portion of the object. Returning through the last lens, they fall on an inclined fluorescent screen, whose resulting light emission controls the output current of an electron multiplier. This current, after further amplification, ultimately controls the intensity of the half-tone lines in the image printed by a facsimile recorder, the image being recorded in synchronism with the displacement of the fine electron spot relative to the specimen surface.

Figure 7 shows the voltage supply unit, the control panel of the scanning microscope, the vacuum chamber, and the recorder. With this instrument numerous pictures have been obtained with resolutions of the order of 50 millimicrons, considerably better than can be obtained with the light microscope. A typical example is the micrograph of carbonyl iron (Fig. 8). The structure of the scanning lines is so fine as to be scarcely visible; the contrast is excellent.

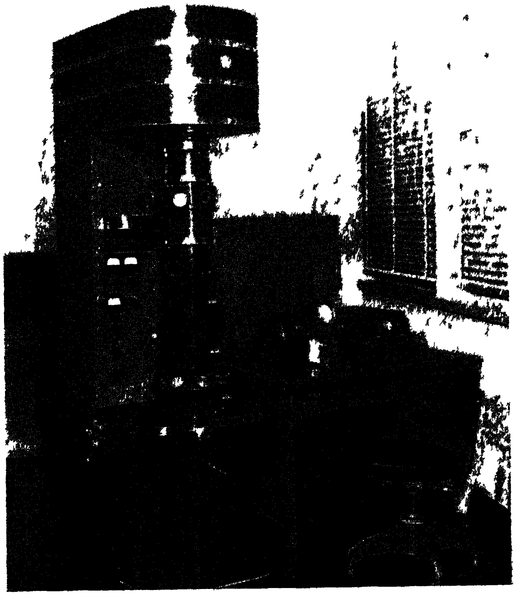


FIG. 9. STANDARD VS. DESK MODEL
THE RCA TYPE B ELECTRON MICROSCOPE TOWERS ABOVE THE EXPERIMENTAL DESK MODEL BESIDE IT.

While the replica technique of examining metallurgical surfaces has to a large extent surpassed in resolution the results obtainable with the scanning microscope, the development of the latter instrument continues.

Small electron microscope. Recently there has been a demand for an electron microscope of simplified design which could be used conveniently as a tool for routine work. To answer this demand a small desk-type electron microscope has been developed in this laboratory. A photograph of this instrument in comparison with a standard electron microscope is shown in Figure 9. Figure 10 is a diagrammatic cross section of this new instrument.

The length of the microscope column, which is inclined so as to present to the observer the final image on the transparent viewing screen at a convenient angle, is only 16 inches. The objective and projector lenses form part of the same magnetic circuit and are excited by a single coil. The magnification by the instrument is 5,000. Since, however, its limiting resolution, and hence its useful magnification, are of the same order as the corresponding quantities

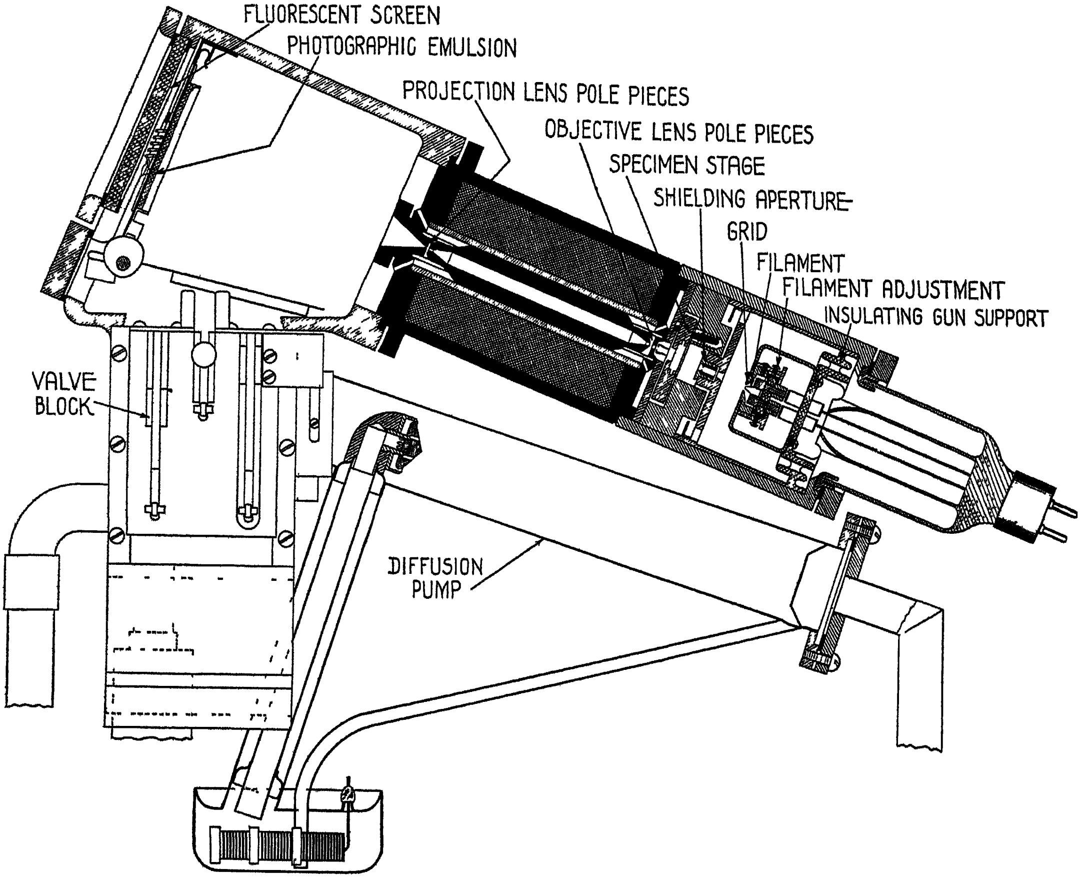


FIG. 10. CROSS SECTION OF THE DESK TYPE ELECTRON MICROSCOPE

of the standard instrument, electron micrographs obtained on fine-grained photographic materials at this relatively low magnification may usefully be enlarged by a factor of about 20. Magnifications lower than 5,000 may be obtained by changing the mechanical setting of the lenses. The operating voltage remains fixed at 30,000 volts. Focusing is accomplished by adjusting the coil current. Since the total volume of the microscope is only about one liter, which can be evacuated in about two minutes, no airlocks are required in either the specimen or the photographic chamber. Mounted on a standard desk, the compactness and simplicity of construction of this small electron microscope make it extremely easy to manipulate and very favorable for routine observations.

The electron microanalyzer. In the preceding sections we have indicated several times that the information which the electron microscope gives can be summed up by the three words—size, shape, and structure. It has also been indicated that the electron optical technique may be applied to answer some of the other problems which arise in connection with research work on finely divided material. Another instrument which has been developed for this purpose is the electron microanalyzer (Fig. 11). With this instrument a chemical analysis of an extremely minute area of an electron microscope specimen can be made. It utilizes a fine electron probe produced in the same way as in the scanning microscope. As the electrons of the probe pass through the selected area of the specimen, some of them suffer a loss in energy which is specific for each element of the periodic table. By detecting and measuring the specific losses in velocity by means of a magnetic electron velocity

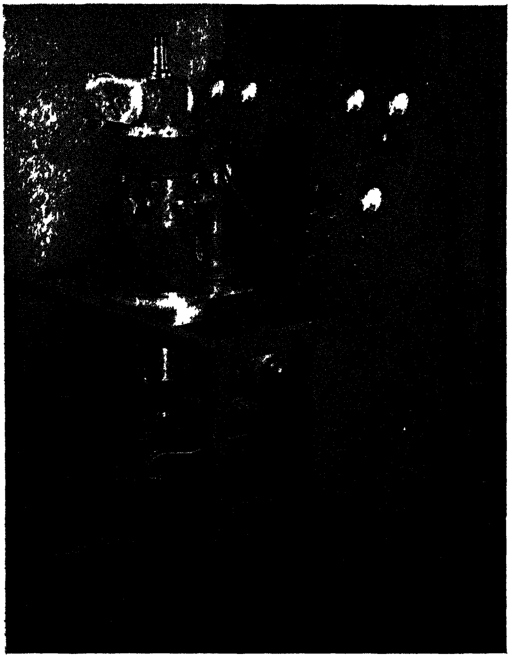


FIG. 11. AN ELECTRON MICROANALYZER

analyzer incorporated in the instrument, it is possible to determine all the elements present in the specimen area being analyzed. An electron microscope is incorporated in the instrument enabling the operator to observe the specimen as a whole and select the area which he wishes to analyze. While this instrument is still in its early stages of development, the results obtained indicate that future electron microscopists will be able to add chemical symbols to their micrographs.

APPLICATIONS

The number of problems to which the electron microscope has been applied[1] in the few years of its existence is literally astounding. In the field of biology they run the entire gamut from the larger anatomical structures of insects through diatoms, cell structures, and bacteria to virus and large organic molecules. In the field of chemical particles it has been used to examine all types of finely divided materials from extremely thin evaporated films through fine colloidal particles and pigment to the larger chemical particles and crystals. With the development of the replica technique the study of the surfaces of materials of all types has also become one of the major applications of the electron microscope. A large part of this work has naturally been of an exploratory type, and many of the results have been incidental to the initial "feeling out" of the possibilities of the instrument. This phase of the application of the electron microscope is now passing, and many investigations of fundamental importance are being undertaken.

In a brief general review of the subject of electron microscopy it is not possible to present a complete survey of the research accomplishments of this new science. In the following discussion, only a few representa-

[1] For a fairly complete list of the applications of the electron microscope, the reader is referred to the bibliography in the Journal of Applied Physics, Vol. 14, pp. 522–531, 1943, by C. Marton and S. Sass.

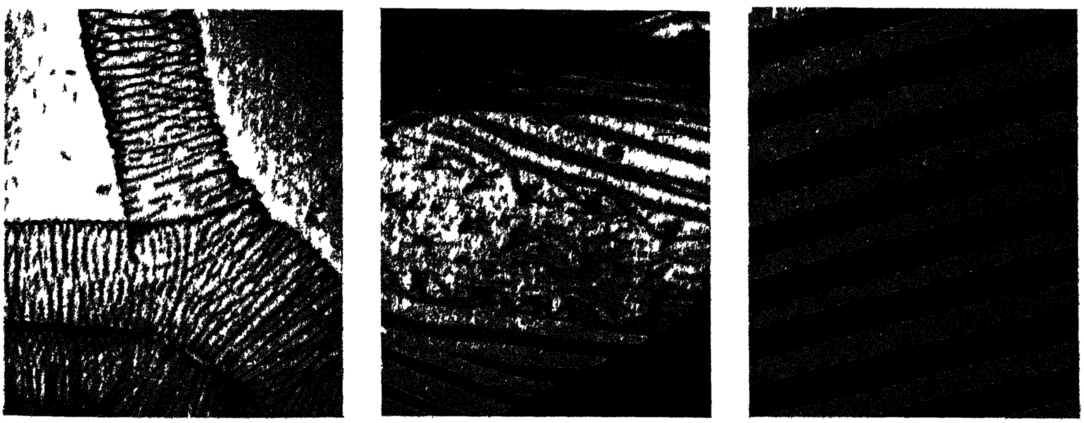


FIG. 12. ELECTRON MICROGRAPHS OF THE TRACHEAE OF A MOSQUITO LARVA
NOTE THE STRUCURE OF THE SPIRAL BANDS (TAENIDIA) OF THE AIR TUBES (TRACHEAE) POSSESSED BY ALMOST ALL INSECTS. THE ILLUSTRATION ON THE RIGHT IS MAGNIFIED ABOUT 8,300 ×; THE OTHER TWO, 2,480 ×.

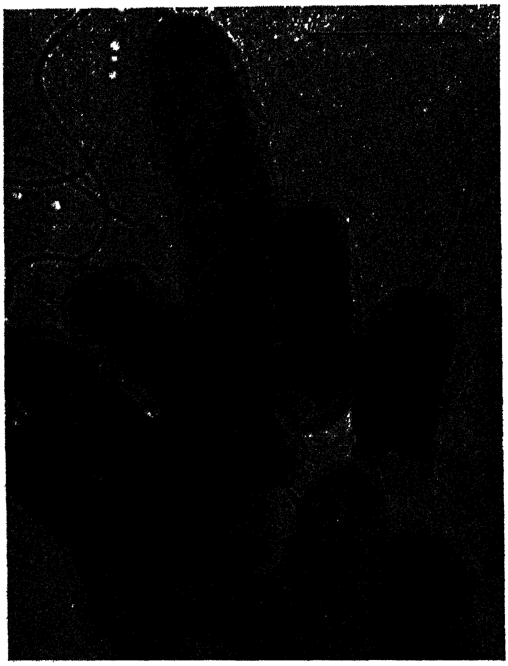


FIG. 13. *VIBRIO SCHULKYLLIENSE*
RIVER BACTERIA SHOWING INTERNAL STRUCTURES AND THE FLAGELLA. MAGNIFICATION ABOUT 19,750 ×.

tive examples of the application of the electron microscope in the various fields in which it has been used will be described.

In the field of biology the electron microscope has been used for some rather cursory examinations of some of the structures of insects. Figure 12 is a series of three micrographs of the tracheae of a mosquito larva and clearly indicates the manner in which the electron microscope can be used to determine the finer morphological details of such structures. The investigations up to the present have been confined to the examination of those parts of insects which, when removed from the insect as a unit, can be examined without further preparation. While some preliminary attempts have been made to examine material which must be sectioned, the results have not been encouraging.

Organisms which normally consist of a single cell, such as diatoms and bacteria, are ideal for observation in the electron microscope. As a result of the increased resolving power of the electron microscope, various types of bacteria can be seen to possess easily recognized characteristics. Consequently Dr. Stuart Mudd and a number of co-workers at the University of Pennsylvania are undertaking an extensive program to investigate and catalogue the morphology of a large number of types of bacteria. This group has already published several papers describing the appearance of various bacteria under the electron microscope. Figures 13 and 14 are examples of the results being obtained.

The extremely minute viruses which cause a number of common diseases in plants and animals have been known for a number of years. More recently some of these viruses have been obtained in a relatively pure form and many of their properties determined. Before the advent of the electron microscope this work was analogous to "flying blind over unknown territory." In spite of this apparent handicap many exact measure-

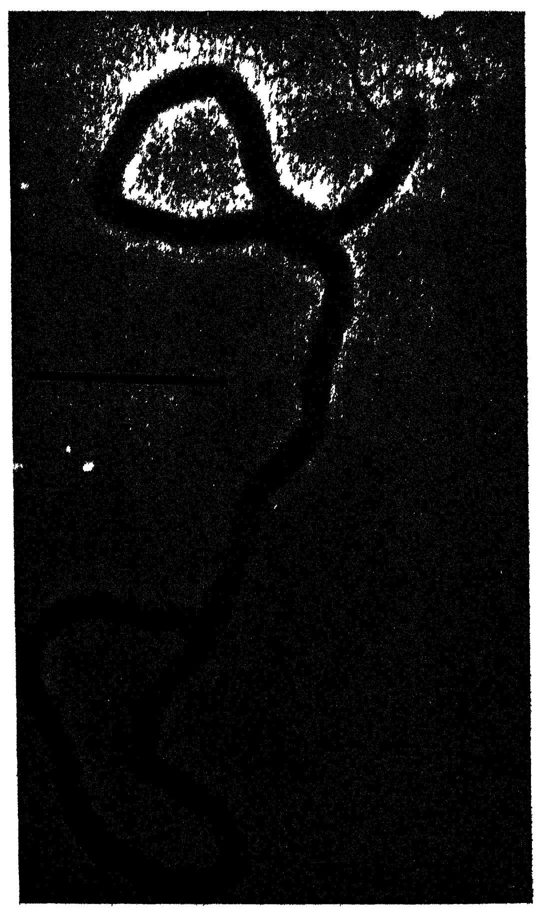


FIG. 14. *TREPONEMA PALLIDUM*
A PORTRAIT OF A SPIROCHETE, THE PATHOGEN OF SYPHILIS. NOTE THE FLAGELLA. ENLARGED 25,700 ×.

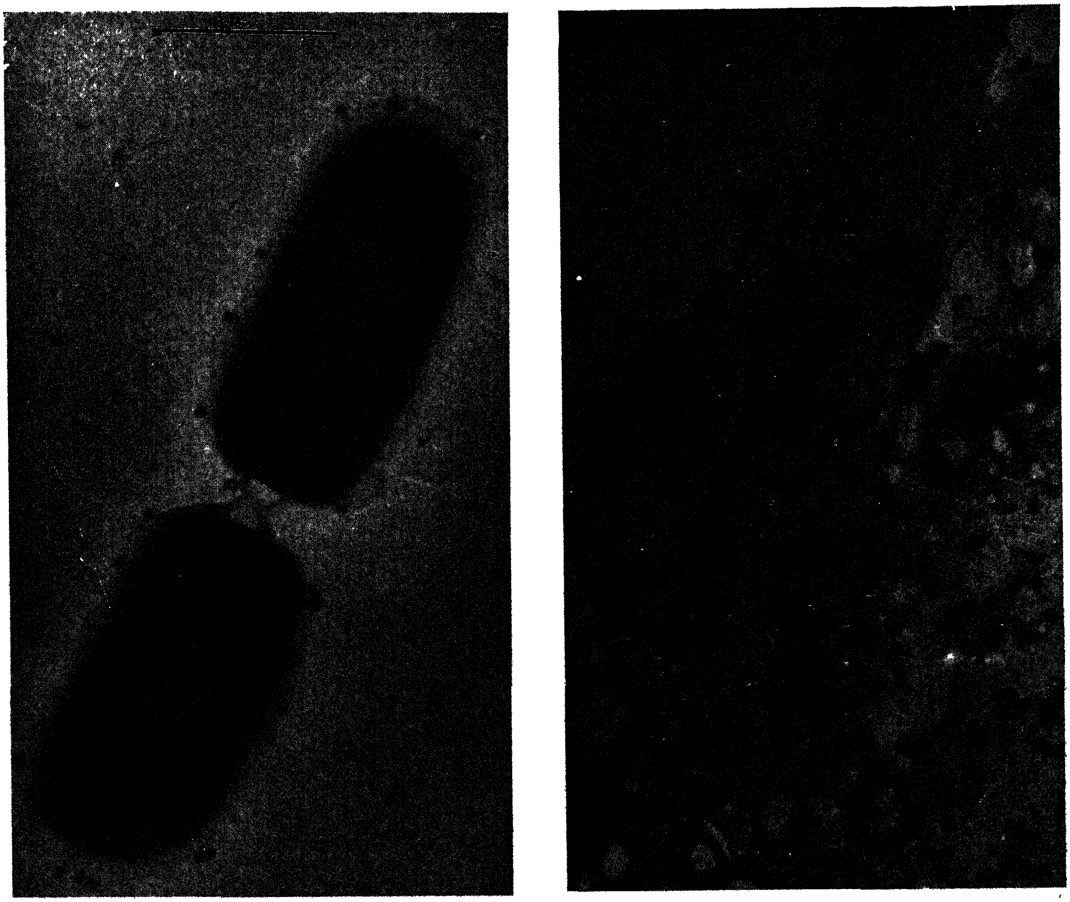


FIG. 15. BACTERIOPHAGE DESTROYING *ESCHERICHIA COLI*
Left, AFTER 15 MIN. CONTACT WITH BACTERIOPHAGE PARTICLES (24,400×); *right,* AFTER 23 MIN. (13,300×).

ments were made and later when the viruses were observed for the first time in the electron microscope, these measurements were found to be extremely accurate. An outstanding example of the application of the electron microscope to the virus problem, and one in which the results obtained surpassed anything possible by indirect methods, is found in the study of bacteriophage. It was known that the bacteriophage particle was a type of virus which could lyse (destroy) the bacteria for which it is specific. Nothing, however, was known regarding the mechanism of the destruction. By applying the electron microscope to the problem, Luria, Delbrück, and Anderson were able to produce a series of micrographs which not only made the bacteriophage particle visible for the first time but also showed that it had a well coordinated structure in spite of its minute size and showed very clearly part of the method by which the bacteriophage reproduced itself through the destruction of its host. Such a sequence of micrographs is shown in Figure 15. It can be seen how one or more bacteriophage particles become attached to and perhaps enter a host cell. After an interval of some fifteen to twenty minutes the host bacterium appears to disintegrate and a large number of newly formed bacteriophage particles, along with other material, are expelled.

The next step down on a size scale brings us in the range of the large organic molecules. A number of these which are large enough to be seen with the electron microscope have already been photographed. Little has been done, however, in this particular

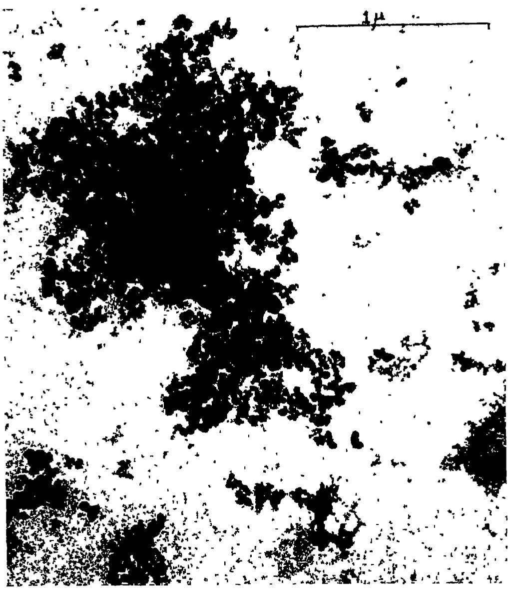


FIG. 16. COMMERCIAL GAS BLACK
SHOWING PARTICLE SIZES. MAGNIFICATION 25,200 ×.

FIG. 17. A CALIFORNIA CLAY
THIN FLAKES AND CUBES. MAGNIFICATION 15,900 ×.

field because the resolving power of the electron microscope is of the same order of magnitude as the particles being observed. This means that the particles themselves do not appear sharp and for the present at least there is no possibility of observing any structure.

The application of the electron microscope to the field of industrial chemistry is probably the most important of all and also the most direct. It is concerned almost exclusively with the correlation between the size, shape, and structure of finely divided particles and the physical and chemical properties of the bulk product. The particles studied range in size from as large as several microns down to molecular dimensions. This range includes almost every material that occurs in a particulate form. By means of the electron microscope particle size distributions can be determined quite accurately. Measurements obtained in this way have the advantage that the shape of the particles is visible (Figs. 16 and 17). It is in the application of the electron microscope to industrial chemistry that the electron diffraction adapter is of most use as an auxiliary means of obtaining information. Transmission-type electron diffraction patterns of finely divided crystalline materials are very readily obtained and give an accurate check on the composition of the material being examined.

As soon as the high resolving power attainable with the electron microscope was demonstrated, it became apparent that metallurgists had a number of problems in which

FIG. 18. SURFACE OF BRASS
REPLICA TECHNIQUE DISCLOSES A GRAIN BACTERIA

this increased resolving power would be of great value. Although, at the time, it did not seem possible to observe metal surfaces directly by means of high magnification electron optical systems, an indirect technique of doing so was forthcoming almost immediately. This involved the preparation of a thin plastic replica of the surface to be examined. The replica was itself of the optimum thickness for examination by means of the electron microscope. The method has been developed rapidly, until, at the present time, replicas can be produced which preserve the detail of the original specimen down to the limit of the resolving power of the electron microscope. Figure 18 is an example of this type of work.

In the preceding paragraphs a very brief survey has been made of the rapidly growing science of electron microscopy. It has been shown how the electron microscope can be used to extend the usefulness of the light microscope in almost every field where the latter instrument is applied. Some of the auxilliary types of electronic equipment which are being developed around the electron microscope have also been described briefly. When the electron microscope was first introduced to practical use about three years ago, it stirred up considerable interest. Some skepticism was evident particularly in discussions on the interpretation of the images. On the other hand, some workers found immediate solutions to old problems and considered the instrument a "modern miracle of science." After three years of intensive research by what is still a relatively small group of workers, the electron microscope is slowly but surely being established in its true role: that of a high-powered aid to our vision. It is only when the electron microscope is used as a visual guide to and a check on the complete investigation of a problem that its maximum value to science is realized.

ZWORYKIN AND HILLIER

VLADIMIR KOSMA ZWORYKIN, E.E., Ph.D., Sc.D., is Associate Research Director, RCA Laboratories, Princeton, New Jersey. He was born in Russia in 1889 and received his degree in electrical engineering at the Petrograd Institute of Technology in 1912. Until the outbreak of World War I he continued his studies at the Collège de France in Paris and during the war he served in the signal corps of the Russian Army. Dr. Zworykin came to the United States in 1919 and was soon employed in research by Westinghouse in Pittsburgh. During that period he became an American citizen and took his Ph.D. at the University of Pittsburgh. In 1929 he became Director of Electronic Research with the RCA Manufacturing Co. and in 1942 the Radio Corporation of America advanced him to his present position. Dr. Zworykin has long been a leader in technological developments in electronics. His books are: *Photocells and Their Applications* (1932), *Television* (1940), and *Electron Optics and the Electron Microscope* (in press). The esteem in which his work is held is indicated by his membership in the National Academy, American Academy, and French Academy of Science, and by the awards that have come to him, particularly the Rumford Medal.

JAMES HILLIER, Ph.D., a research physicist, has been working with Dr. Zworykin at RCA since 1940 on the development of electronic microscopy. Only twenty-nine years ago Dr. Hillier was born in Brantford, Ontario. His undergraduate and graduate work was done at the University of Toronto where he took his Ph.D. in physics in 1941. From 1939 to 1940 Dr. Hillier was a research assistant and demonstrator at the Banting Institute of the University of Toronto Medical School. Like those other young pioneers, Banting and Best, who preceded him at Toronto, Dr. Hillier and Dr. Prebus (now at Ohio State) became pioneers, not in the field of medicine, but in electronic microscopy, which will certainly aid medical research. At Toronto in 1939 Dr. Hillier and his associates were the first on this continent to build a successful electron microscope of high resolving power. For RCA he designed the first commercial electron microscope to be made available in the United States. He has worked on several of the "associated developments" described in the present article and is now developing a new electronic tool for microanalysis. Already an Electron Microscope Society of America has been formed, of which Dr. Hillier is now vice president.

CLEVELAND—A GREAT LAKE'S PORT

By E. WILLARD MILLER

CLEVELAND, situated at the mouth of the Cuyahoga River on Lake Erie, lies in one of the best commercial locations in America. Located strategically between the Lake Superior iron ores and the Appalachian coals, Cleveland has been able to solve its problems in handling these bulk commodities efficiently and easily. It has become one of the country's leading ports, handling as much tonnage in seven months as Boston, Philadelphia, or Baltimore do in twelve. Cleveland is also frequently considered the financial heart of the Great Lakes. At present more than 320 ore-coal boats, divided into 15 or 16 major fleets, are largely controlled from the offices located on the city's public square. Between 5,000 and 6,000 vessels enter and leave the port each year carrying freight valued at $225,000,000 to $250,000,000.

Early development of the port. Nearly every important settlement on the Great Lakes developed at the mouth of a river or stream which offered protection from wind and waves during loading and unloading of vessels. As the New England Yankees came along the shore of Lake Erie in 1796 looking for a place to settle, they stopped at the mouth of the Cuyahoga because of its harbor possibilities. Trade began almost immediately in furs bought from the Indians, and in 1800 Cleveland was made a port of entry. However, even at this early period certain natural barriers in the harbor restricted the free movement of vessels. Across the river mouth a sand bar obstructed the entrance for a greater portion of the year. The spring floods usually destroyed it, but the bar appeared again during the low water stage of summer and autumn. Boats, therefore, frequently had to anchor outside and unload into scows and lighters.

The first plan to improve the river harbor came with the beginning of construction in 1825 of the Ohio and Erie Canal, which was to extend from Cleveland to Portsmouth, Ohio. Thus, in 1825, the Federal Government appropriated $5,000 for the construction of a pier which began about 500 feet east of the mouth and extended into the lake for 600 feet nearly at a right angle to the shore. The pier was unsuccessful because sand filled in behind it. In 1827 an additional $10,000 was granted in order to eliminate several meanders in the lower two miles of the stream where silting took place. The new direct channel began where a bend carried the river within 1,000 feet of the lake. A dam was built across the stream at low-water stage, and with the aid of some digging the next high water cut a straight channel to the lake. Gradually the mouth of the old river filled in, and the upper portion of this bed is now used as a place of anchorage and wharfage. By 1840 about $75,000 had been spent for harbor improvements, docks, and warehouses.

With the completion of the Ohio and Erie Canal in 1832, Cleveland gained undisputed leadership among the Ohio ports and was second only to Buffalo on the Great Lakes. The increase in commerce was immediately noticeable, particularly in passenger service, for the new waterway enlarged the possibilities of lake travel and freightage by providing a means of carriage into the State and on to the south by way of the Ohio and Mississippi Rivers. A large section of the country was provided with an outlet for products hardly marketable before. In 1838 more than 58,000 tons of goods, valued at $2,444,000, were exported. Of these commodities flour and wheat had the greatest value and pig iron and lumber the largest bulk. In the same year 67,600 tons were imported, more than 90 per cent of which was merchandise. As a result of Cleveland's advantageous position, her population grew from 600 in 1820 to 17,034 in 1850.

Increase in iron ore traffic. Although the development of lake transportation was steady and important for the period, it was still limited in 1840. Because of the lack of plentiful harbors and the storminess of Lake Erie, only 48 schooners, 8 steamboats, and 2

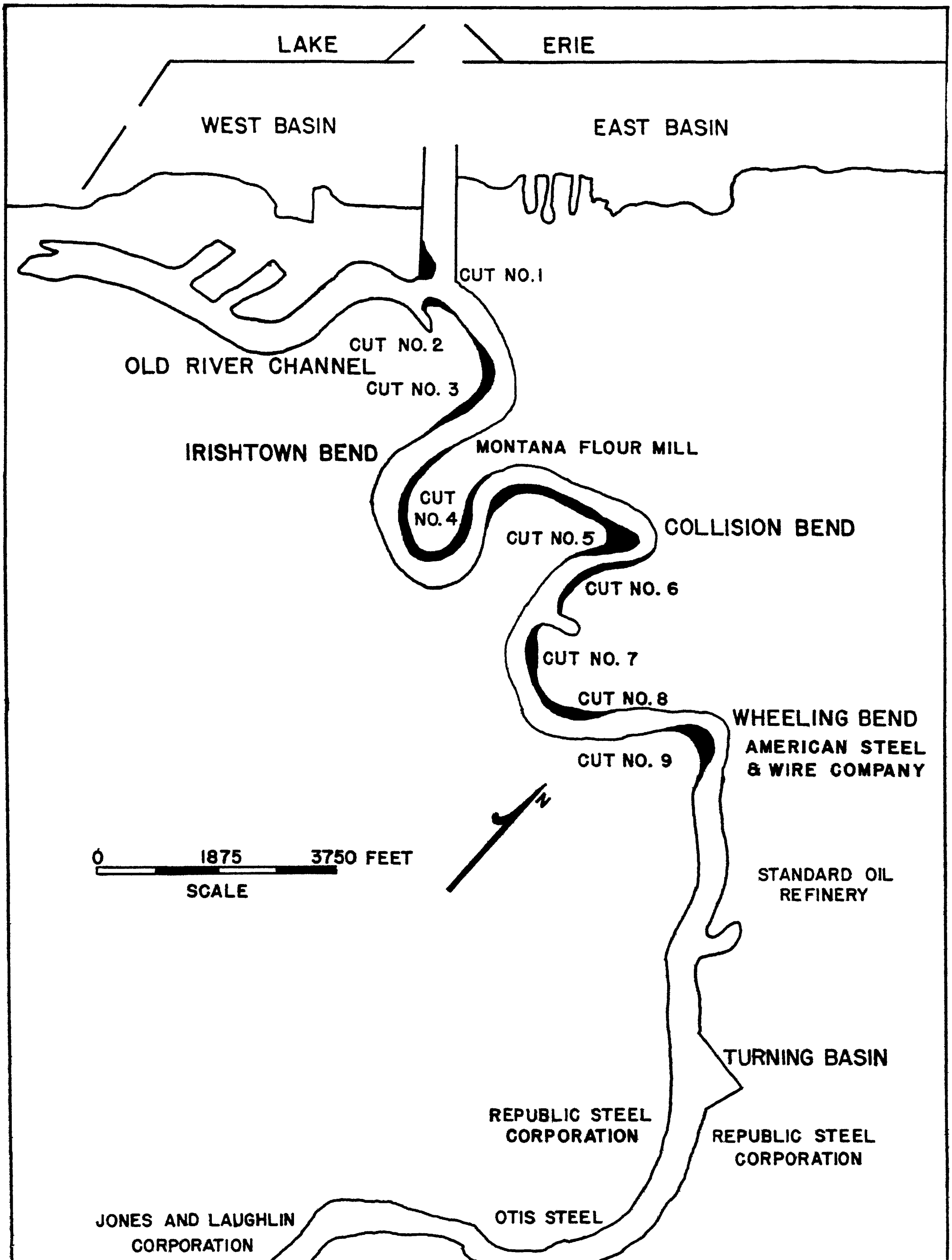


FIG. 1. HARBORS OF CLEVELAND, OHIO.

OUTER HARBOR OF THE WEST AND EAST BASIN IS THE COMMERCIAL HARBOR. INNER HARBOR ALONG THE CUYAHOGA IS THE INDUSTRIAL HARBOR. SHADED AREAS SHOW WHERE THE RIVER CHANNEL WAS WIDENED IN 1940.

FIG. 2. THE MOUTH OF THE CUYAHOGA RIVER.

brigs plied the lake in 1838. Lake traffic became tremendous only after the discovery and development of the iron and copper ores in the upper lake region in the 1850's, and the shift of the iron and steel industry to western Pennsylvania in the 1860's. Since Cleveland was one of the largest and most prosperous cities on the lakes in the 1850's, much of the capital to develop the ore resources came from its business men. From 1850 to 1890 Cleveland groups maintained a near monopoly in iron trade, for they con-

FIG. 3. INNER HARBOR NEAR HEAD OF NAVIGATION.

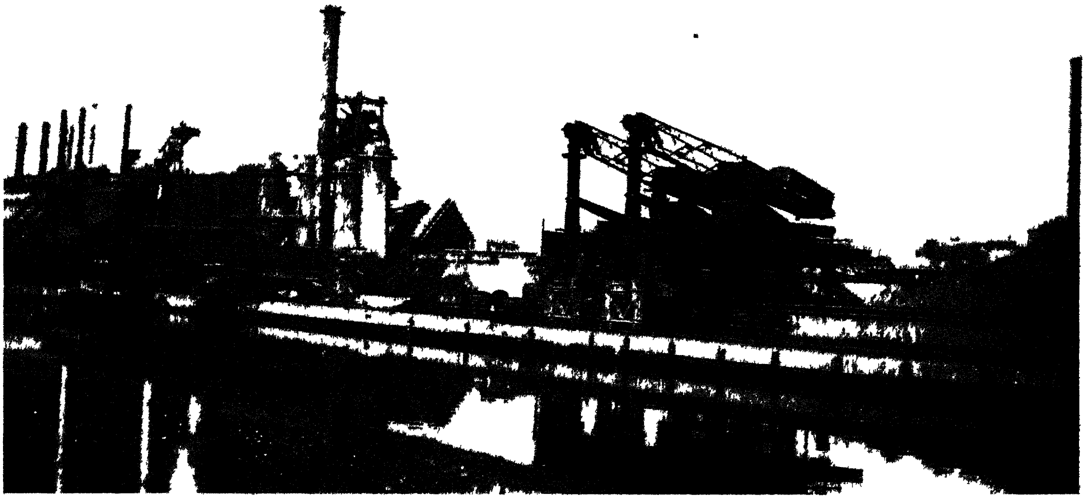


FIG. 4. INNER HARBOR DOCKS AND BLAST FURNACES.

trolled the Marquette iron range, the only important producing area. The golden era in Cleveland's ore trade came from 1880 to 1890 when the number of its vessels increased from 175 to 241 and the tonnage from 64,287 to 176,804 In 1890 the total United States tonnage constructed aggregated 294,122, of which 108,525 were built on the Great Lakes; of this amount Cleveland's shipyards built 39,095 tons, 13 per cent of the total and 36 per cent of the entire tonnage of the Great Lakes. The Cleveland district, with the

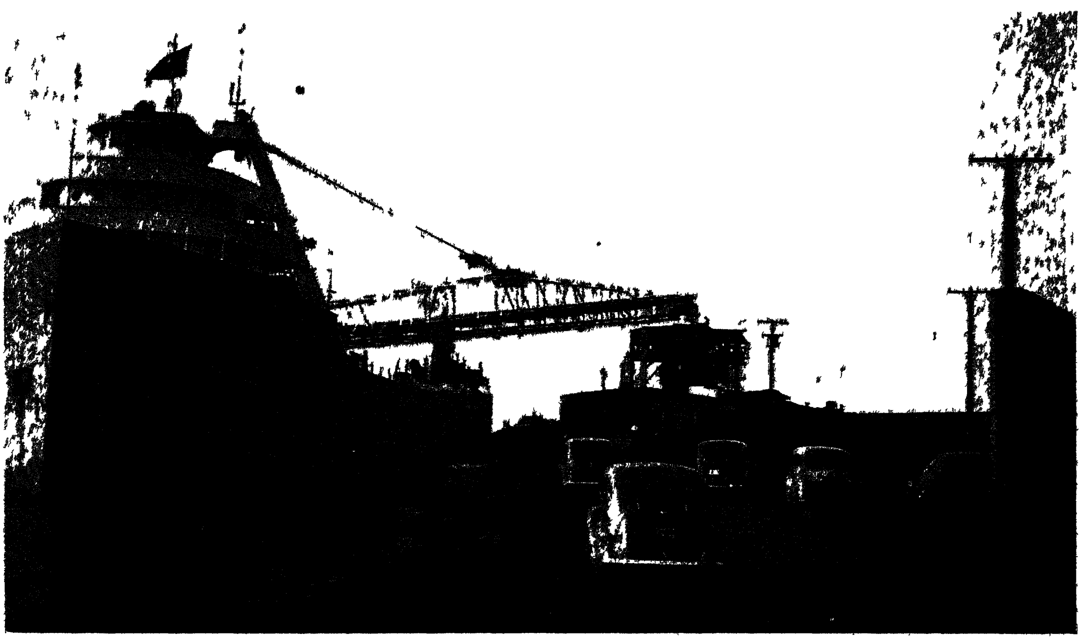


FIG. 5. AUTOMATIC UNLOADING LIMESTONE BOAT AT THE MOUTH OF THE CUYAHOGA.

single exception of the Clyde region of Scotland, was the largest shipbuilding point in the world. Cleveland business men controlled all the Lake Erie docks, except those at Erie and Buffalo, and owned at least three-fourths of the vessels in the ore trade.

Rise of competition and harbor problems During the 1890's a number of problems developed that gradually threatened Cleveland's position in lake trade. With the discovery of other iron ore ranges in the 1880's and particularly the Mesabi Range in 1890, Cleveland business interests no longer controlled the entire ore region, and other lake ports began a period of rapid expansion.

Besides the increasing competition, another problem developed which was to plague Cleveland for nearly 50 years. As long as lake boats remained small, the Cuyahoga River, Indian name for crooked river, could handle the traffic efficiently. However, the newer, longer vessels exceeding 480 feet experienced great difficulty in negotiating the curves, which between the mouth of the river and a point two miles upstream totaled 855 degrees of curvature or two and three-eighths circles. Because of these curves and because the ships had to be towed (self-propulsion would have churned up mud and caused shoaling), bulk freighters required about five hours to travel from the mouth of the Cuyahoga to the upper steel plants, a distance of five miles. After delivering their cargo, the freighters had to be towed out stern first, for they could not turn in the river. Towage costs were approximately \$400 a round trip. Other operating expenses averaged about \$100 per hour so that the cost of a round trip varied from \$1,200 to \$1,500. Another problem created by the sharp curves was the lack of river frontage for docks since boats needed the entire width of the Cuyahoga to move around the bends. Many lake captains made the statement that they would rather go to any port on the lakes other than Cleveland.

The modern harbor. The present harbor at Cleveland is divided into two parts, a breakwater-enclosed area of the lake called the outer harbor and the lower stretches of the Cuyahoga, the inner harbor (Fig. 1). The improvements of the inner harbor, which handles about 90 per cent of the traffic, was delayed long past the time of imperative necessity. The delay was partially due to the vagueness of a general policy as to division of responsibility among the Federal, state, and city governments. In the case of

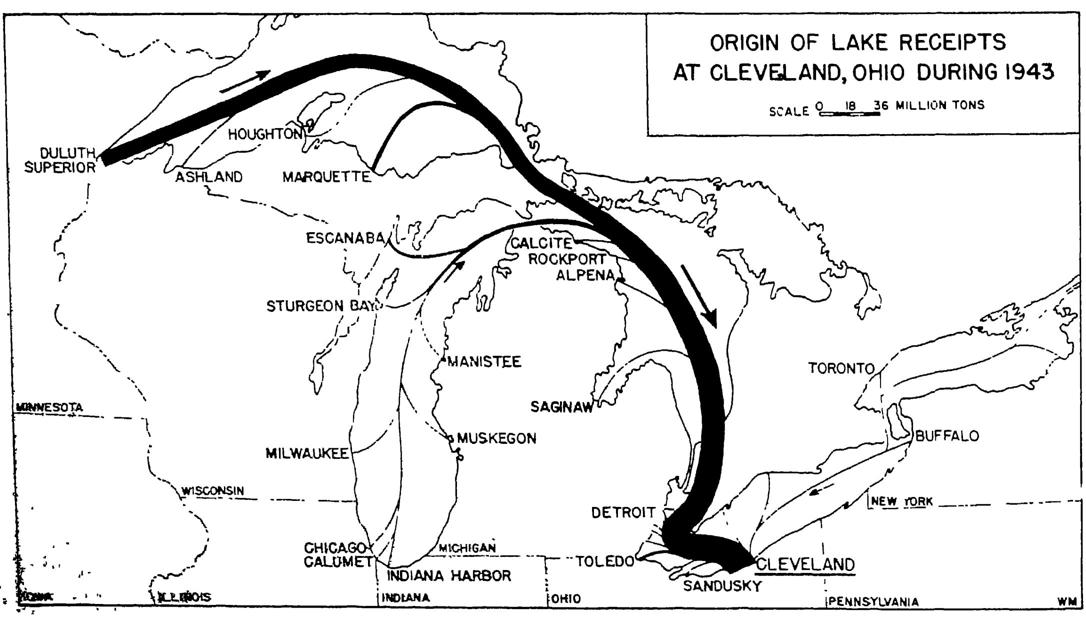


FIG. 6. ORIGIN OF LAKE RECEIPTS AT CLEVELAND DURING 1943.

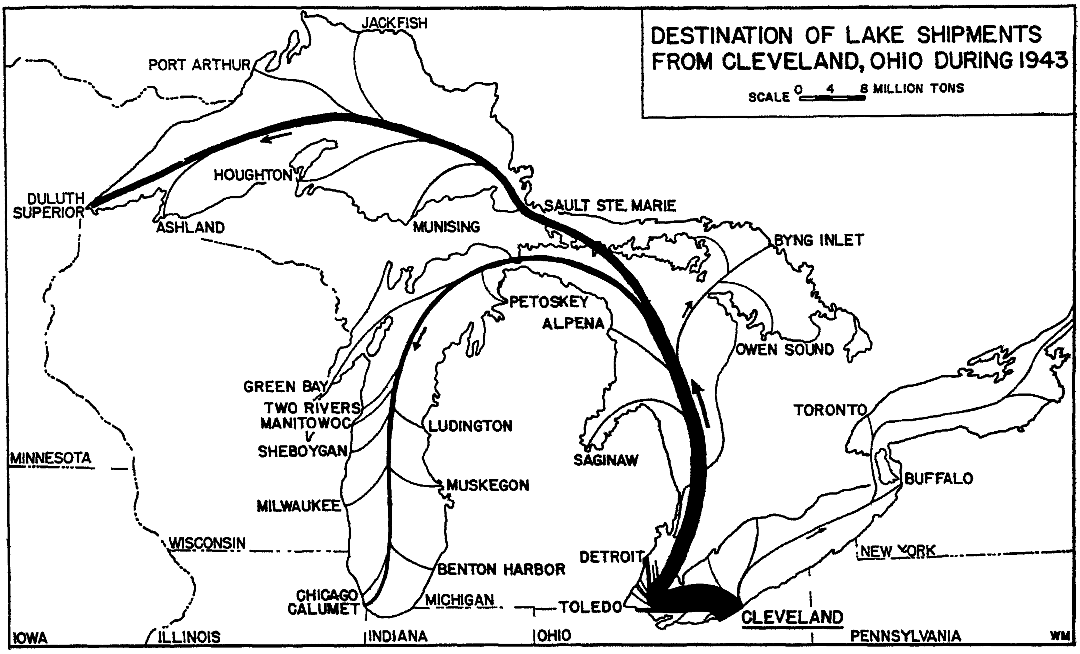


FIG. 7. DESTINATION OF LAKE SHIPMENTS FROM CLEVELAND DURING 1943.

Cleveland the Federal Government improved only the outer harbor; the inner, or river, harbor remained the responsibility of the city. Following this plan, the Federal Government, under the authorization of River and Harbor Acts of 1875, 1886, 1917, 1935, and 1937, completed the construction of an extensive breakwater, which ranges from 1,700 to 3,500 feet from the shore line and protects an area of 1,300 acres of water. The lake harbor is divided into an east basin, which is open the full width of the east end, and a west basin, which is partially closed on the west. The outer harbor has only a few piers and is used mostly for passenger vessels, repair docks, and warehouses.

Although the outer harbor developed a long protected shoreline, it has played a rather insignificant part in the lake traffic of Cleveland, for the heavy industry is concentrated on the flats along the Cuyahoga (Figs. 2, 3, 4, and 5). Little was done to improve the inner harbor until the latter part of the 1930's, and as a result the port has suffered a permanent loss of tonnage in certain commodities, particularly coal. From 1920 to 1940 lake traffic as a whole increased 65 per cent, while Cleveland's portion decreased 11 per cent. After considering eight separate plans between 1912 and 1937, the necessary improvements were begun in 1939. They included cutting back nine of the sharpest bends (Fig. 1), widening the channel so that nowhere is it less than 90 feet and in places widens to 270 feet, the construction of a turning basin, 17 feet deep and 600 feet wide, 4.75 miles upstream (Fig. 1), and raising or rebuilding low railroad bridges so as to increase safety and speed of lake vessels. A system of docks with a total length of about 13 miles has been laid out, about half of which, containing 43 of the 58 wharves and docks in the harbor, is now in use. Engineers have estimated that 70 years ago the cost of straightening the river would have been about $350,000; the modern improvements, including the destroying and reconstruction of bridges, buildings, and docks, cost approximately $11,000,000.

Commerce. The modern commerce of Cleveland consists chiefly of bulk commodities, such as iron ore, coal, coke, crushed stone, sand, and gravel, although the movement of petroleum products, automobiles, and manufactured iron and steel products is increasing in importance. The average tonnage of all traffic handled for the prewar

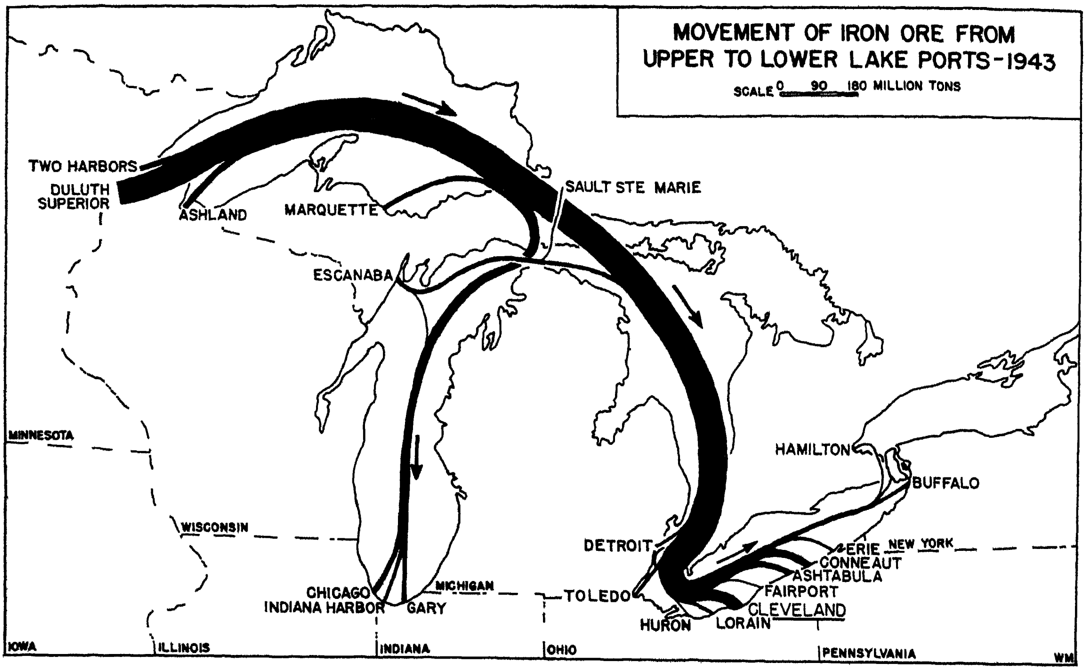


FIG. 8. MOVEMENT OF IRON ORE FROM UPPER TO LOWER LAKE PORTS IN 1943.

period 1929–1938 amounted to 10,965,340 tons per year, a decrease from the 12,219,249 tons handled annually from 1920 through 1928. Tonnages, however, have fluctuated greatly from a low of 4,234,525 tons in 1932, a depression year, to 17,385,842 in 1937. Since the beginning of World War II in 1939, the tonnage handled at Cleveland has increased from 25 to 30 per cent, due largely to the greater shipments of iron ore (Figs. 6 and 7). Fluctuation in tonnage from year to year illustrates the responsiveness of lake traffic to changes in general economic conditions.

Of the lakewise receipts, iron ore represents between 75 and 80 per cent of the total; as a result Cleveland has remained the largest iron ore port on the lower lakes. The receipts of this commodity averaged 6,583,164 tons per year from 1929 to 1938 in comparison with a total average tonnage of 8,357,481 received during the same period. Fluctuation in tonnage of iron ore is marked; in 1929, a peak year, 11,139,432 tons were received, whereas only three years later receipts of iron ore were only 963,840 tons. Since 1939 all previous tonnage records have been surpassed. In 1942, 13,799,639 tons and in 1943, 12,423,308 tons were received (Fig. 8). The dominance of Cleveland as the leading iron ore port lies in its financial control of the iron-coal fleets, its early start, and in the large consumption of iron ore in local furnaces along with its favorable position in supplying ores needed in the Pittsburgh district, the Shenango Valley, and the Steubenville area. Although local mills use between 35 and 40 per cent of the ore received, Cleveland normally sends more ore to the interior iron and steel centers than any other lake port.

Crushed stone is second in tonnage of the commodities handled, averaging over 800,000 tons per year, approximately 10 per cent of the total receipts. Cleveland is second only to Buffalo in the amount of stone handled. Most of the crushed stone originates at Calcite, Rockport, and Alpena on Lake Huron and at Marblehead on Lake Erie. Petroleum products, mostly gasoline and fuel oils, have been increasing in recent years. The remaining tonnage of lakewise receipts consists of scrap iron, iron and steel shapes, pig iron, coal tar, sulphur, cement, flaxseed, and phosphate rock.

One of Cleveland's greatest problems is the difference between lakewise receipts, which total 75 per cent of all traffic, and lake-

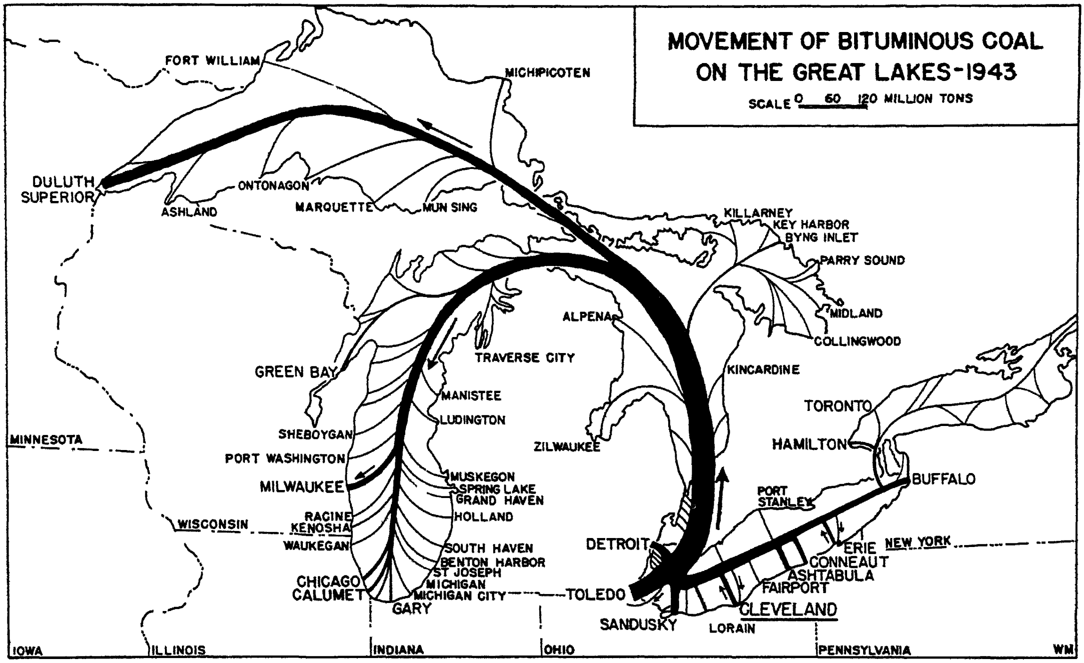


FIG. 9. MOVEMENT OF BITUMINOUS COAL ON THE GREAT LAKES IN 1943.

wise shipments which account for 16 to 17 per cent of the water-borne commerce. This means that many vessels must leave Cleveland without a cargo. Of the lakewise shipments, coal plays a dominant role, usually consisting of 70 per cent of the total. Of the lake ports, Cleveland is sixth in tonnage of coal shipped, averaging 1,250,000 tons per year. The large coal traffic of the lakes developed when Cleveland's harbor facilities were poor, and other lake ports, particularly Toledo, gained most of this trade (Fig. 9). Cleveland's industry also consumes a large percentage of the coal coming to the city. The shipment of iron and steel in rolled form, bars, structural steel, pig iron, and manufactured articles account for 20 per cent of the total. The principal ports of destination for these products are Ecorse, Detroit, and Saginaw, Michigan; Calumet Harbor, Illinois; and Duluth, Minnesota. Petroleum products are also important in outbound traffic, as well as automobile bodies and trucks.

Cleveland's trade is almost entirely domestic; only a limited amount of export and import trade is developed with Canada. The principal imports are sand and gravel, paper, newsprint, flaxseed, and scrap iron, while coal comprises 95 per cent of the exports.

The water-borne traffic of Cleveland is directly related to the iron and steel industry. With the improvements of the harbor, raw materials can be assembled in Cleveland at a cost as low as any place on the Great Lakes. This was demonstrated when the Republic Steel Corporation in 1939 chose Cleveland as the site of its new continuous wide-strip mill. Although the port has been greatly handicapped in the past, the improvements make it possible for Cleveland to compete with harbors that can accommodate the largest freighters, thus marking a new era in the handling of lake traffic.

SCIENCE IN FRENCH CANADA

I. INTELLECTUAL TRADITIONS

By PIERRE DANSEREAU

THE war is showing the nations of North and South America how much they have in common, how truly American they all are. Together they have agreed to defend their land, their freedom. But it does not follow that freedom has the same meaning for all of us. Indeed, the material, intellectual, and spiritual background of each American nation is such that its pattern of life, the very fabric of its individuality, is different from that of its neighbor, not to mention nations at other latitudes.

"One world!" is boldly proposed by a great American politician. "*Liberté, égalité, fraternité!*" said the French republic of yesterday, and no doubt that of tomorrow will re-echo the motto. But equality and liberty, if they are basically the same everywhere, have different components in the minds and consciences of different peoples.

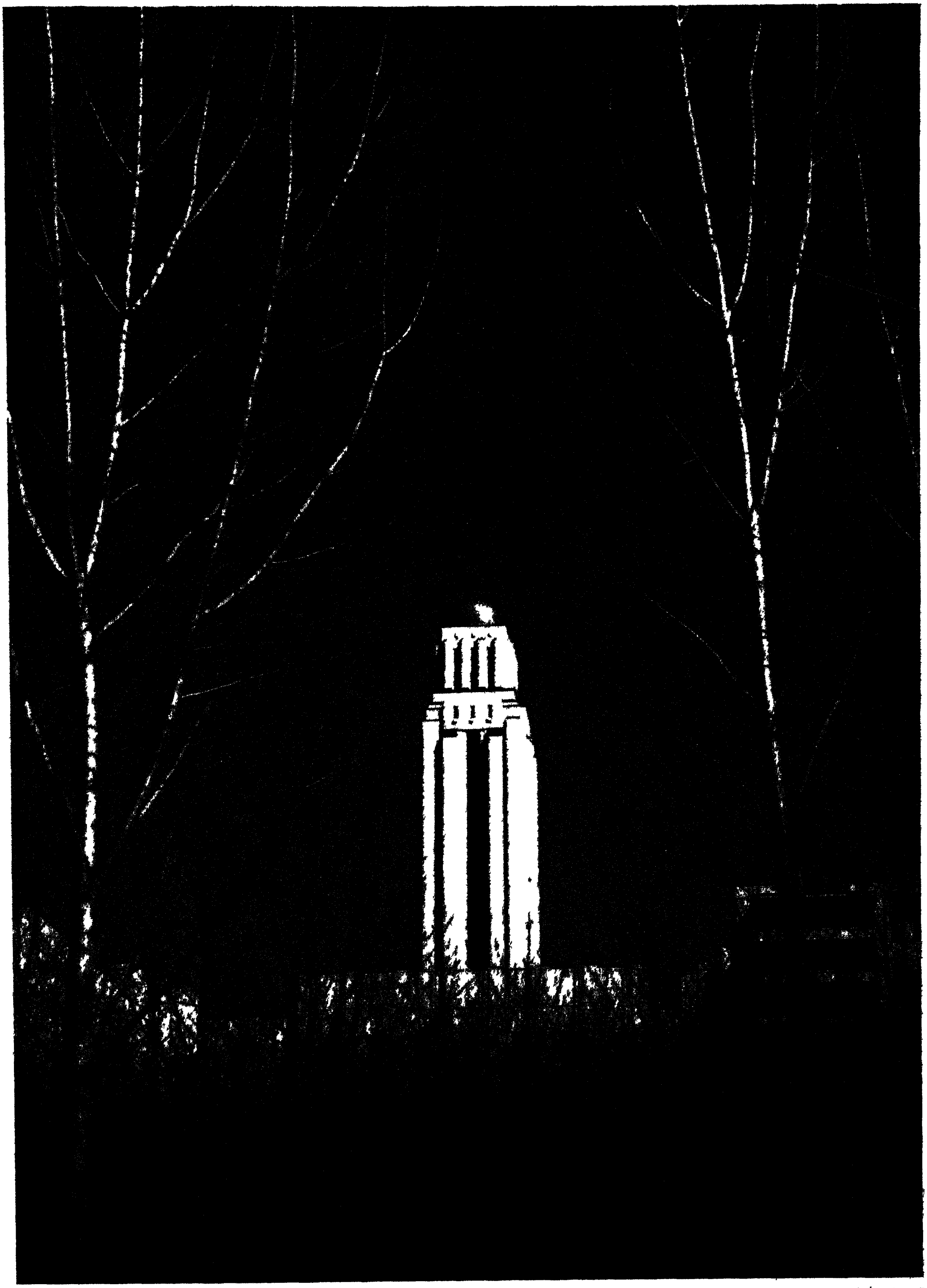
No peace, no freedom, no permanent international concord can exist without the recognition of this diversity. Are we not fighting against the will of one nation to impose its way of life upon all other nations? That nation thinks that it knows best. Such is the justification of all dictatorship, of all authority, for that matter. But that attitude is shared—it sometimes seems unconsciously—by people who profess truly democratic ideals. Was it not Jean-Jacques Rousseau himself (whose political convictions are quite above suspicion) who said: "*Il faut forcer les hommes à être libres?*"—an over-realistic and very dangerous principle, to say the least.

There can be no peace but in mutual understanding. And that in turn can come only from an unprejudiced approach to the ways and habits of other nations, and the appreciation of the genuine elements of their culture even when these spring from an uncongenial religious or intellectual, or even political, background. That, I know, is very much to ask, too much perhaps. But who does not hope for some grain of wisdom to be sown and to germinate in these days of affliction?

My purpose, however, is not to plan a better world and even less to tell American scientists how broad or how open their minds should be. The aim of this article is to draw a brief outline of science and scientific life in French Canada and to cite a few facts not generally known to our American colleagues. It also attempts to give some explanation of French-Canadian intellectual development, especially in the field of science.

The "cours classique." After 1763, when Canada was ceded to England by France, there remained some 60,000 colonists. For three-quarters of a century these people, whose numbers steadily increased, were largely deprived of intellectual leadership. Relations with France had been completely severed. No books in a language they could understand were available. The only educated men were the priests and even they, in some cases, were so only by comparison. Education was entirely in the hands of the clergy. The bishops created the *petits séminaires*, in which young men were taught Latin and Greek, French and a little mathematics, and the rudiments of science. These institutions were above all, and some of them have remained almost to this day, a mere stepping stone to the *grand séminaire*, where formal studies in theology lead to ordination in the priesthood.

It is therefore evident that this *petit séminaire* (which assumed the role of both high school and college) dispensed an education in harmony with its basic purpose: the training of the clergy. Its program centered about the Greco-Latin humanities and the philosophy of Aristotle and Saint Thomas Aquinas. The rigid discipline of the classic authors, both in style and logic, was the mainstay of that system. The whole weight of the mind, so to speak, was made to bear on synthesis, on the end product of intellec-



André de Tonnancour, Montreal

THE MAIN TOWER OF THE UNIVERSITÉ DE MONTRÉAL

tual endeavor which has to do with the assembling of facts, not with their unearthing. In fact, there was very little in this method which had any earthiness about it, the great romantics of French literature themselves being regarded with much suspicion by the masters.

One must bear in mind the relative universality of this desiccation process under its many forms in the Victorian era. Its French-Canadian expression was, on the whole, less dismal than one might think, the natural good humor and love of life of the race tending to check all excessive rigidity with characteristic French realism.

However that may be, the intellectual gymnastics involved in intimate and everyday contact with Xenophon, Cicero, and Pascal produced men of considerable intellectual versatility. Some were remarkable orators, but none were good businessmen and few were able technicians.

The "liberal" professions. However, all students of the *cours classique* did not become priests, and from the beginning many of them were oriented towards law or medicine. In fact during a very long period when a sort of superstition attached to these so-called liberal professions, all others were notoriously less "honorable." It hardly seemed worth while putting a boy through the relatively expensive *cours classique* to make anything less of him than a *docteur* or an *avocat*.

It would be somewhat outside the scope of this brief survey to draw a detailed picture of these two professions. Let it suffice to outline some of the major traits as an illustration of the outcome of the educational system as a whole and of the characteristic intellectual leanings of men who were the very core of the élite.

Civil law in the Province of Quebec is based on the Napoleonic code. The French-Canadian jurist follows French tradition in that he presents and judges his case more in accordance with doctrine than with jurisprudence. This is a significant fact and an outstanding symptom of the vitality of the French-Canadian mentality in a predominantly Anglo-Saxon country where custom and precedent, not theory, are the rule. The existence and functions of the notary are also typically Latin and do not exist in the other eight provinces of the Dominion.

In medicine an analogy can be found in the current mistrust of exclusive specialization and in insistence on general examination and clinical methods. It is no doubt a direct result of a humanistic upbringing that no function of the human body may be considered separately unless complemented by a general clinical diagnosis. A large number of French-Canadian physicians have carried on postgraduate studies in France, and the influence, both direct and indirect, of French medicine is very much alive in Canadian medical practice today.

Other professions are more recent in the history of French Canada: engineering, agronomy, forestry, accountancy, business management, etc. For many years, there were no schools in his country where a French-Canadian could receive training in these subjects in his own tongue. If he could not afford to go to France, which was often the case, he went to Anglo-Canadian or American institutions. There he found that he had first of all to catch up with the language, and then with some of the facts which his schoolmates had already learned in school or college. He found that his "general culture" was a useful tool, but he also observed that the materials to be wielded were strangely unfamiliar. In fact, he experienced what his masters of the *petit séminaire* had predicted; namely, that his mind was now ready to assimilate, but that he knew very little. His baggage of common scientific facts was slight indeed. More often than not, however, this handicapped student turned out quite well, and in many instances did brilliantly in the end. The founders of French-Canadian schools of engineering, agronomy, forestry, chemistry, and economics all belong to that category: they have been reformers in education and have created institutions of solid scientific standing.

Religious background. The priest, however, is the most authentic product of the *cours classique*, or French-Canadian system of education. Primarily it was devised for him and to this day it has essentially fulfilled the purpose of developing those quali-

F Gerard Simard, S J, Montreal

THE NEW BUILDING OF UNIVERSITÉ DE MONTRÉAL ON THE SLOPE OF MOUNT ROYAL
THE INSTITUTION ORIGINATED IN 1878 AS A BRANCH OF UNIVERSITÉ LAVAL; BECAME INDEPENDENT IN 1920.

ties most necessary to the exercise of his functions

By the force of circumstances, those functions were very diverse in the past, and they remain so today in many rural districts where the *curé* is the best educated person in his community. His counsel was taken and carried much weight, not only in spiritual matters where his authority is unchallenged, but in domestic, educational, political, and economic matters as well. Very much has been made of the clergy's role in keeping the French-Canadian people distinct by safeguarding their culture along with their faith. Canon Groulx,[1] the foremost exponent of such views, would have us think that the French-Canadian people owe their very existence to the leadership of their Roman Catholic clergy. It may be well to point out, with Albert Pelletier,[2] that the greater credit may well belong not to those in authority, but to the laymen and to the lower clergy, nearer to the people and more of the people, whose uncompromising attitude was more decisive than the more polished performances of the higher clergy.

The religious background is therefore extremely important in the study of intellectual evolution in French Canada. The very universality of Roman Catholicism facilitates the comprehension at least of some of its elements. We shall not discuss its more intimately religious and mystical aspects: our subject is the intellectual and social influence of the Church as an institution, not its spiritual significance.

Anyone at all familiar with the Church of Rome, and willing to consider it under its historical aspect, cannot but marvel at its unparalleled wisdom. No doubt, to many—and especially to those of a different faith—it appears as a reactionary force Some widely publicized events have tended to establish this view. But let it be remembered that if Rome silenced Galileo, the French Revolution beheaded Lavoisier. There are appar-

[1] Superscript numbers refer to "Literature Cited" which will appear at the end of Part II.

ently some institutional necessities quite independent of the progressiveness of the organization itself. These are unfortunate, but present in all institutions of long standing, even the most constructive. But this is neither the place nor time to open a debate on such a far-reaching question. Many excellent discussions of this point have appeared, for instance, in Jacques Maritain's recent book, *The Nights of Man and the Natural Law,* 1943, New York.

It is sufficient to say that the Catholic Church has undergone various adaptations, throughout many centuries and in many countries. What we are concerned with is the form it has assumed in French Canada and the bearing of religious pressure on scientific and intellectual life here.

The long-unquestioned position of the clergy as a dominant caste, so to speak, has forcibly introduced a religious element into the acts of everyday life. This of course has only been possible because the nation as a whole subscribed wholeheartedly both to the Catholic credo and to the authority of the Church. Such grounds are eminently favorable to an encroachment of the clergy on secular affairs. Also such a long-established dominance becomes institutional in character and in the end highly conservative.

The Catholic clergy in Quebec has produced some of the most brilliant, intelligent, and constructive minds Canada has known. It comes as no surprise that these same men—much as the tories of Old England, whose contribution to the grandeur of their country is not questioned—were defenders of their class privileges and of the dominance of theology over science.

The people of French Canada have been and generally remain deeply conscious of their religious duties. Today they dispute the clergy's monopoly of education and challenge some of its age-old political teachings,

André de Tonnancour, Montreal

THE NEW BUILDING OF THE UNIVERSITÉ DE MONTREAL

SEEN THROUGH THE OAKS OF MOUNT ROYAL. A SKI-TOW HAS BEEN ESTABLISHED ON THE UNIVERSITY CAMPUS.

Livernois, Quebec

THE CENTRAL PART OF OLD UNIVERSITE LAVAL, IN QUEBEC

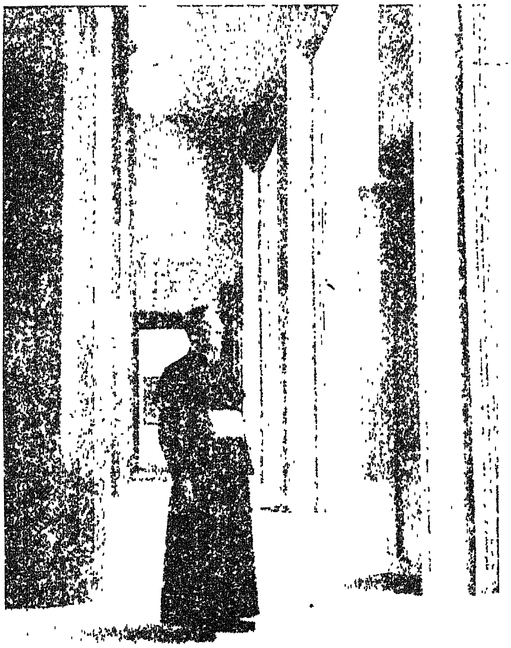
IT WAS FOUNDED IN 1663 AS A SEMINARY BY MGR. DE MONTMORENCY LAVAL; BECAME A UNIVERSITY IN 1852.

but it is significant that even the avowedly heterodox are religiously minded.

The minority complex. The response obtained by the clergy in the exercise of its authority was further enhanced by the necessity for leaders which was, and still is, very keenly felt by French Canadians in all walks of life. I need hardly insist on the fact that a minority, living in self-defense in an imperial state, had to entertain a constant awareness of its problems and stand close by its leaders. Every man was made to feel responsible in some way for the survival and progress of the group as a whole. By the force of circumstances, and especially through the play of imperialist policy, no French Canadian was allowed to forget that he was part of a minority whose rights were forever being questioned, not to say violated, in a number of small and inconspicuous ways.

Such a restless and often negative attitude is no doubt difficult to understand and seems mean and hopeless to the member of a great, unified nation. However that may be, it makes the need for authority, command, discipline, and what rightist parties call *order*, much more imperious than the need for equality and freedom. Indeed these, at certain moments in the life-history of a minority, seem remote and maybe hopeless goals, if not beautiful but meaningless symbols.

It therefore becomes easy to understand that the best intellects that we have produced—especially in the nineteenth century—were drained towards action, mostly political, and not towards the more speculative forms of intellectual pursuit. A keen, if misdirected, sense of duty drew these talented



André de Tonnancour, Montreal
MGR. OLIVIER MAURAULT
PRESENT RECTOR OF THE UNIVERSITÉ DE MONTRÉAL.

men away from art, literature, and science and into the public arena. Most of them were artisans of *bonne-entente* and worked constructively towards an harmonious development of Canada "*a mari usque ad mare.*" Men such as Papineau, Cartier, LaFontaine, and Laurier were essentially men of good will who went to the extreme limit of concession compatible with the dignity of the group they represented. Whether their optimism was well founded remains an open question.

The anticlerical strain. Through political channels, however, and not through literary activities, new ideas were introduced which were a menace to clerical supremacy. Louis-Joseph Papineau, the chief leader of the 1837–1838 insurrection, was the initiator of a tradition of rebellion against the all-embracing monopoly of the Church. The spiritual descendants of Papineau have not been very numerous, but they have kept up the struggle all these years and have obtained many a victory, mostly under the banner of the liberal party.

Such questions as evolution, the rights of strikers, and birth control have given rise to bitter and highly prejudiced debates, where the defenders of so-called liberal views had a hard time of it. On the whole, the tone of these controversies was very much the same as in the Middle West of Mr. Sinclair Lewis at the same period. If the conservatives were capable of pigheadedness, the liberals were at times noted for their naïveté.

Today, the left wing has rallied quite a number of orthodox Catholics, including members of the clergy itself. To them, it seems that there is cause for alarm in the achievement of too much secular power by the Church. They think of France in the nineteenth century and of Spain and Mexico in the twentieth and direct their efforts to self-reform to avoid a revolution.

Today, the dominating influence in French Canada is still ecclesiastical. It covers the whole field of education, whether directly or indirectly. The colleges are affiliated with the two Catholic universities, Laval in Quebec and Université de Montréal in Montreal, but they are actually autonomous, and the universities exercise very little control on either studies or discipline. They merely superintend the examinations and dispense the B.A., which is the culmination of eight years' study.

The youth movements are also in the hands of the clergy. Foremost at all times have been the Jesuits, whose keen sense of organization and excellent psychology have allowed them to control many generations of sound and enthusiastic young men and women.

Some trade organizations also are endowed with an *aumonier*, whose opinion is sometimes decisive in matters not obviously connected either with faith or morals.

The laymen, however, have come into their own in the arts, literature, and primary education. Of course in finance, commerce, the administration of justice and of the state, ecclesiastical intervention is remote if not totally absent.

(*To be concluded*)

APPLIED MICROSCOPY OF HAIR

By LEON AUGUSTUS HAUSMAN

The microscopist was peering through his microscope at some fragments of hair which, under a high magnification, showed evidences of having been subjected to rough treatment of some kind. A few weeks before, the body of a young boy had been found torn and mutilated in a northern forest. Tracks of a mountain lion or cougar were thickly imprinted in the light snow about the body. Tracks of both boy and cougar, leading up to the spot, indicated that for a long time the beast had trailed its victim. A large reward had been offered to the person who could produce the killer. Soon afterwards two large cougars were shot nearby; and two hunters claimed the reward, each one asserting that his beast had been the slayer of the little boy. In the stomach of one of the cougars were found some masses of hair. But such masses in the stomachs of the big cats are not uncommon. Was this particular mass made up of *human* hair? This was the question the microscopist was trying to answer, and finally did answer in the affirmative, even though the hair had suffered some disintegration. The answer had been found after the hair-shafts of the sample had been treated in such a way as to bring out certain structures which it was necessary to examine minutely before attempting to come to a conclusion about the matter. What were those structures? What was it necessary to do to these fragments of hair before they could be made to yield their secret under the microscope? Do the hairs of humans differ from the hairs of other mammals? Do the hairs of mammals in general differ from each other? Do the hairs of humans differ from each other so that personal identification is possible even from minute fragments? Will the microscopic examination of hair fragments enable a microscopist to suggest what sort of treatment the hairs may previously have undergone? These, and many other questions growing out of them, indicate some of the matters to which the microscopist of mammalian (including human) hair is giving more and more attention.

Another example: this time the microscopist was examining wool fibers from two different samples of fabrics under illumination by polarized light. One sample contained a very large proportion of fibers which were bent, bruised, fractured, frayed at their ends, and showed traces of different dyes in the same fiber. The fibers were, moreover, of varying diameters, and many of them showed cuticular scales (the fine scales which lie on the outside of all mammalian hairs) torn and otherwise changed from their natural form. Such things could not have been seen by the naked eye, but to the eye behind the microscope were clearly revealed. The observations suggested to the microscopist that this particular fabric was made up of materials which had been used in a fabric before, and had been torn apart and subsequently rewoven. The second sample exhibited under the microscope nothing but long, unbent, unbruised, unfrayed fibers, with their scales intact, and all more or less of the same diameter. And the microscopist knew from experience what this state of affairs indicated.

Again (and all these are actual cases), a fur was called by the name of a certain animal. But examination of its component hairs under the microscope revealed that they had been clipped and dyed a deep hue. Furthermore, a study of their cuticular scales, cores, and pigment granules proclaimed that they had grown in the skin of an animal of quite another sort—a clear case of "a different breed of cats."

How does the microscope reveal these things? It does so by making clear the various minute structural elements that go into the composition of a hair-shaft—structural elements which can neither be eradicated nor altered without leaving plain traces of such tampering. In such ways the microscope often plainly proclaims that identification or

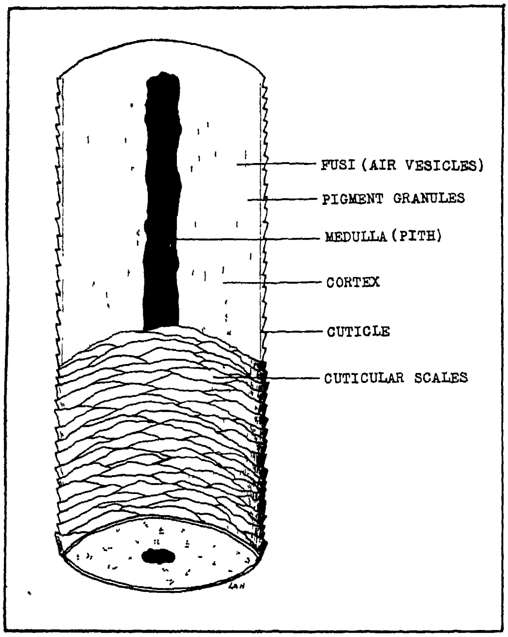


FIG. 1. SECTION OF HUMAN HEAD-HAIR SHOWS THE RELATIONSHIPS OF THE SIX STRUCTURAL ELEMENTS EMPLOYED IN COMPARATIVE MICROSCOPY.

diagnosis, or in some instances even justice, literally "hangs upon a single hair."

Not long ago some burial fabrics of remote and uncertain date were dug up from some South American Indian sepultures. Did the people who wove these fabrics persist until after the Spanish Conquest? This was the question propounded to the heavy brass microscope whose focusing screws the investigator was manipulating. It was known that the Spaniards had brought the first sheep into the region of the graves. Had the microscopist been able to detect sheep wool in the structure of these cerements, it would have helped in the settlement of an historical question.

In a central New England state a biologist is desirous of finding out what mammals inhabit a certain isolated mountain. He collects the excrement of wildcats, which are common there. These nocturnal cats have all unwittingly been acting as the biologists' "corps of collectors," catching and devouring assiduously the smaller mammals of the mountain and leaving in their excrement accurate records, in the shape of masses of hair, of what they have devoured. The microscopist recognizes these hairs and traces them to their source; and the biologist's census of the mammals of the mountain is the more complete—thanks to his wildcat assistants!

A company making felt mats is having difficulty with the felting, or close and successful compaction, of the finished product. Microscopic examination of the material which felts and holds most satisfactorily reveals that it is filled with the smaller, finer hairs of the animals, whereas the loose, unsatisfactory product is composed of only the larger, coarser hairs of the animals. The finer, smaller hairs possess large, outwardly-projecting scale edges which catch and mesh together well and so help to form successful felts; the larger hairs possess small, tight scales whose edges project hardly at all and hence these hairs do not catch and hold but slip past one another, and the resulting felt is weak and easily pulled apart. Furthermore, the microscope shows that a too-vigorous cleaning process is removing too much of the hard, gritty, extraneous matter from the surfaces of the hair-shafts—is removing something which is actually aiding in the felting of the material.

The structures which go into the make-up of a typical human hair, as well as those of other mammals, are indicated in Figure 1. The outside of the hair-shaft is completely overlain by a layer of thin, transparent scales, known as the cuticular scales. These overlap one another like the scales on the body of a fish or the shingles on a roof. This is the condition in a large number of animal hairs. Or the scales may be set within one another like a pile of glass tumblers, or folded about one another's bases like a pile of calla lilies. For examples of these see Figure 3 and look at Nos. 12, 10, and 11 in the order given. Notice that the free edges of these scales point outward and upward toward the tip of the hair-shaft. Even without a microscope one might guess by fingering a hair that it is barbed. If a hair is held between thumb and forefinger of one hand and pulled between the same digits of the other, the feel of the hair will depend on whether the free end is its tip or its base. If the tip is free, one is scarcely conscious of the movement of the hair between the

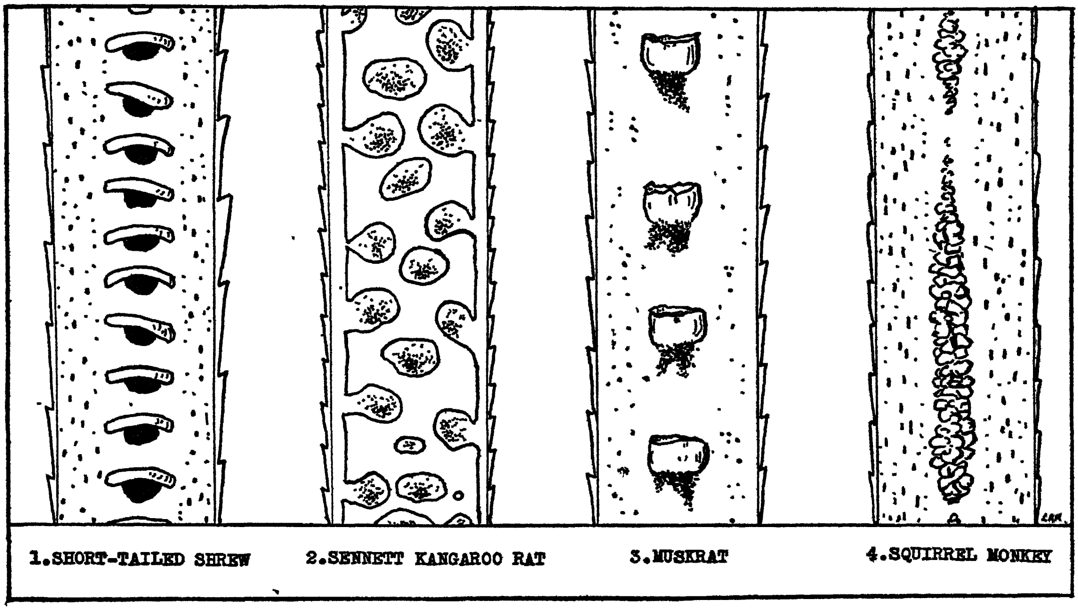


FIG. 2. FOUR HAIR-SHAFTS SHOW MARKED DIFFERENCES IN PIGMENTATION
THE HAIRS WERE SELECTED FOR THEIR NEARLY UNIFORM COLOR. THEY DIFFER IN DISTRIBUTION OF PIGMENT.

thumb and finger; if the base is free, one is conscious of resistance to the movement—of a sensation that might be called vibratory, caused, of course, by the unidirectional scales catching in the skin. The same conclusion may be drawn by simply rubbing a hair between thumb and forefinger; the base will always move away from the fingers.

The scales differ in form, size, and relationship in different animals, and in hairs of different diameters. They do not contain coloring matter in their natural state. Consequently, when the microscopist sees a hair-shaft with its scales colored, he knows that the hair has been dyed. This is often an important bit of information, especially if only a minute fragment of a hair-shaft is available for examination. The scales of some hairs are very delicate and easily injured by rough treatment. The microscope will show this. Or again the microscope will tell you whether you are looking at a hair from an otter, a beaver, or a rabbit—from the size and form of the scales. Notice the great variety of forms of cuticular scales of the hairs shown in Figure 3.

Sometimes the scales of the hair do not help the microscopist much in his analysis; he then turns to another element of the hair-shaft structure, the medulla, which is a sort of "pith" running up through the center of the hair-shaft, and forming, as it were, a sort of core. It is not present in all hairs; the very finest, like those from bats, are without it. Wherever it is present, it forms an important part in the determination of the source of a hair sample, though alone and unrelated it cannot be used for this purpose. In human hair, especially, the kind of medulla which a hair-shaft possesses is correlated with the diameter of the hair-shaft; at least a correlation has been found in the study of 483 specimens of human head-hair taken from individuals ranging from three hours to ninety-one years of age. Medullas consist of masses of shrunken and tangled cells and assume many forms (Fig. 3). In this picture they are drawn as they appear through the microscope with the light thrown up through the hair-shafts from below. In some medullas there are masses of coloring substance arranged in characteristic patterns for the species of animal bearing the hair—a very important fact for the microscopist. The way in which light is reflected from the medullas of hairs in the mass gives certain sheens and colors to the hair.

Scales and medullas are the first structures that the microscopist studies, for these are the larger, more easily seen elements in the

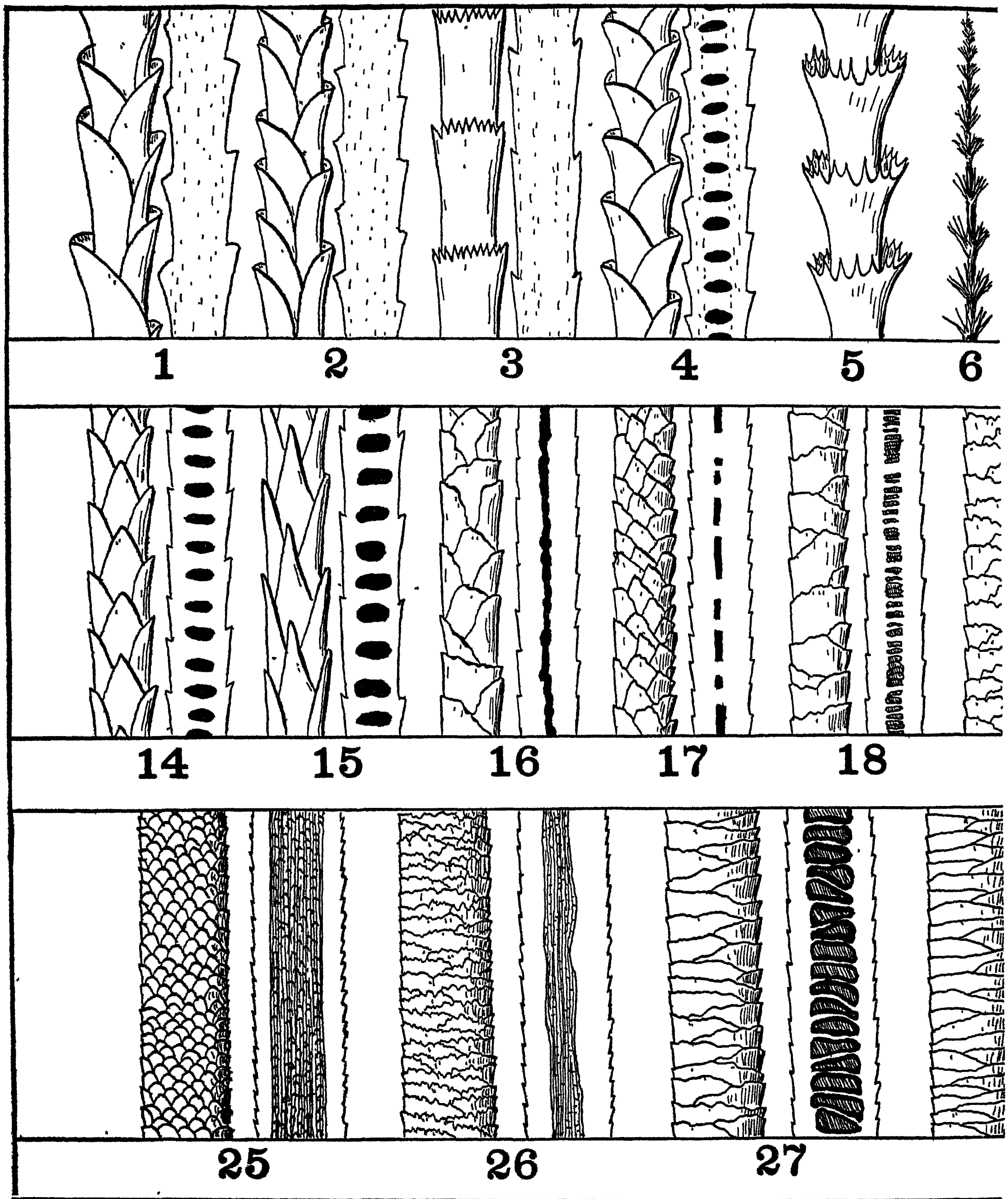


FIG. 3. REPRESENTATIVE HAIR-SHAFTS FROM VARIOUS MAMMALS. LEFT USUALLY THE MIDDLE PORTION OF THE FUR- OR UNDER-HAIR IS SHOWN. MAGNIFICATION VARIES; DIAMETERS

1. Hammer-headed Bat (*Eupomorphorus anurus*)
2. Spotted Bat
3. Intermediate Bat (*Mormoops intermedia*)
4. Malay Vampire Bat
5. Free-tailed Bat
6. Tip of hair of No. 5.
7. Wrinkled-lipped Bat (*Nyctinomus bocagei*)
8. Base of hair of No. 7
9. Pipistrelle (*Pipistrellus subflavus*)
10. Brown Bat (*Myotis lucifugus*)
11. Mastiff Bat (*Molossus sinaloae*)
12. Civet (*Arctogalidia fusca*)
13. Coypu, or Nutria (*Myocastor coypus*)
14. European Mole (*Talpa europea*)
15. Star-nosed Mole (*Condylura cristata*)
16. Red Kangaroo (*Macropus rufus*)

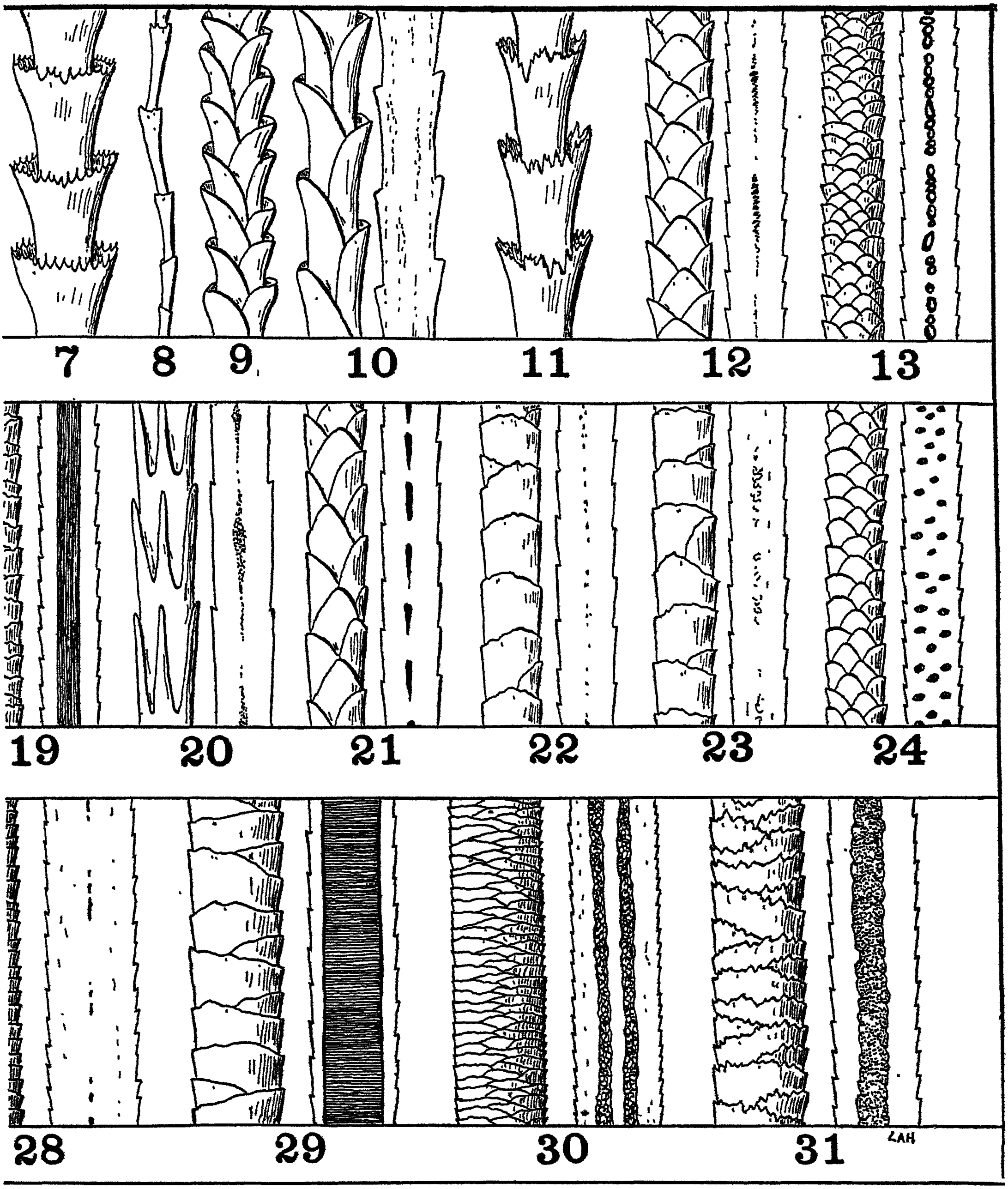


FIGURE OF PAIR SHOWS THE SCALES; RIGHT, THE MEDULLA, IF PRESENT
OF HAIRS 1 TO 24 RANGE FROM 8 TO 30 MICRONS; THOSE OF HAIRS 25 TO 31, FROM 50 TO 150 MICRONS.

17. Aye Aye (*Chiromys madagascariensis*)
18. Bactrian Camel (*Camelus bactrianus*)
19. Gray Kangaroo (*Macropus giganteus*)
20. Otter (*Lutra vulgaris*)
21. Racoon (*Procyon lotor*)
22. Vicuna (*Lama vicuna*)
23. Sheep wool (Merino)
24. Pocket Rat (*Dipodymys agilis*)
25. American Pronghorn (*Antilocapra americana*)
26. Percheron, mare
27. Sea Lion (*Zalophus californianus*)
28. Mammoth (*Elephas primigenius*)
29. Thompson's Gazelle (*Gazella thompsoni nasalis*)
30. Fossil Ground Sloth (*Nothrotherium shastense*)
31. European Hedgehog (*Erinaceus europeus*)

structure of the hair-shaft and require only moderate powers of magnification. However, it is not always the magnification that is the determining factor in the success of the study of minute objects, but the way in which the object under examination is illuminated. We may magnify an object to fifteen or sixteen hundred times its original size, but if our focus is not sharp and our lighting bad, we may as well use a pocket lens!

The bulk of most hair-shafts is not made up of scales and medulla but of an apparently solid, semitransparent rod composed of many elongated, closely compacted cells. This element of the structure of a hair is known as the cortex (Fig. 1). Scattered about within and among its component cells are minute round or oval granules of pigment substance, which chiefly give a hair its color. They are called pigment granules (Fig. 4). They are related in definite ways and are arranged in definite patterns according to the color of the hair-shaft. They are shown in all the illustrations except Figure 3. Notice the relationships of these granule patterns to the colors of human head-hair as shown in Figure 4. Hair pigments are not always in the cortex; sometimes, as previously mentioned, they are present as masses of different sizes in the medulla of the hair (Fig. 2). Hair pigments may also be present in the form of a clear, diffuse stain in the cortex. The cuticle, or substance of the scales, however, is uncolored. The microscope often tells much about even a minute fragment of hair from the size, shape, patterns, and numbers of its pigment granules or masses. Relatively high powers of the microscope are necessary for the study of the pigment granules of hairs.

Among the structural elements of human head-hair, to which attention has been especially paid, are minute vesicles or chambers lying among the cells of the cortex of the shaft. Although well-known by various names to students of trichology, they had been neglected until 1932 when the writer began the study of these elements; first in a series of hair-shafts from some 200 species of animals, and then in a still larger series of human head-hairs. For aid in the collection and study of these specimens the writer was indebted to the late Aleš Hrdlička of the United States National Museum in Washington and to Miss Elizabeth Wynkoop, then Instructor in Zoology in the N. J. College for Women, Rutgers University, and also to several of his students. The results of this first survey of the air-vesicles of hair-shafts was reported in a paper, "The Cortical Fusi of Mammalian Hair Shafts," in *The American Naturalist*, October, 1932, and the study of the series of 400 hair-shafts from human heads was reported in abstract at a meeting in December, 1934. With respect to the air vesicles of the hair-shaft it was then said that "unusual correlations sometimes encountered in hair-shafts, or modifications of the structure of the component elements may constitute individual variations, which, upon further study, may very well prove to have diagnostic value in aiding in the determination of hair specimens of problematical origin." This was also hinted at in the paper, "Histological Variability of Human Head-Hair" (*American Journal of Physical Anthropology*, March, 1934).

Inasmuch as the vesicles had been little studied, had been called by many different names, and were always cortical in occurrence and fusiform in appearance, the term *cortical fusi* was employed in the first paper, a term which has subsequently been adopted by other writers.

The relationships of these cortical fusi in the hair-shafts of the mammals below man is now being further investigated, but several cases of recent emergence in the writer's experience, in which it was necessary to endeavor to establish personal identification by means of hair-shaft examination, resulted in a special prior study of the status of these elements in the shafts of hairs from the human head.

In the human head-hair, as the proliferation of the hair-producing cells about the papilla pushes the young shaft upward through the neck of the follicle, the cortex cells are not at first long and fusiform, as in the mature hair-shaft, but are irregularly and elongatedly ovoid, drawing out into their characteristic spindle form as the shaft reaches, and emerges from, the mouth of the follicle. As this process continues, the cortical cells carry upward between them many

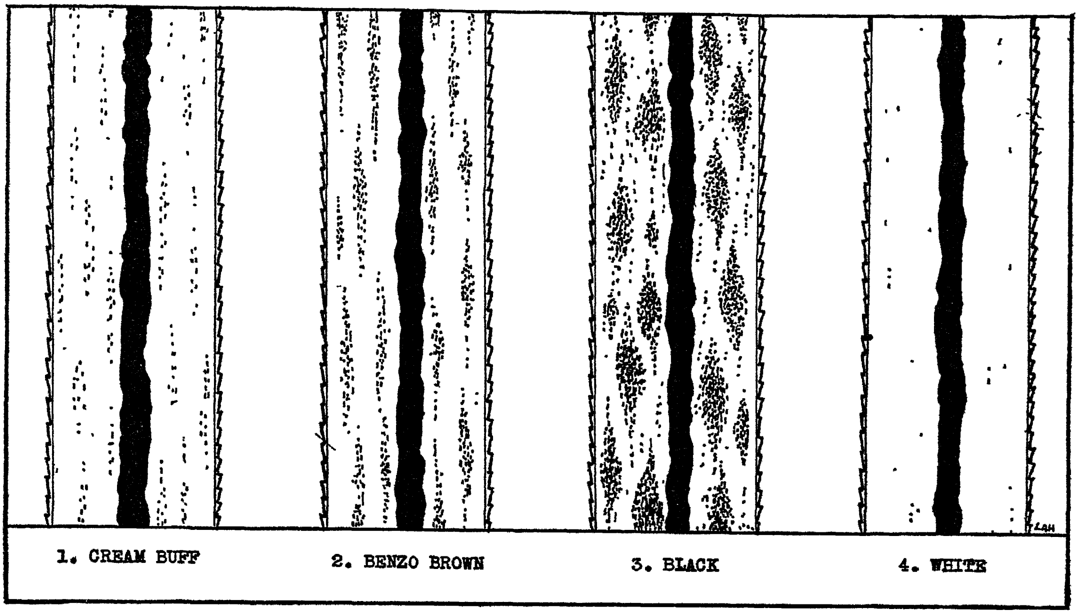


FIG. 4. TYPES OF PIGMENTATION IN HUMAN HEAD-HAIR
COLOR OF HUMAN HEAD-HAIR VARIES WITH THE NUMBER AND DISTRIBUTION OF CORTICAL PIGMENT-GRANULES. CREAM BUFF (RIDGWAY) IS A LIGHT YELLOWISH-BROWN, WHEREAS BENZO BROWN IS A MEDIUM BROWN.

elongated cavities filled with tissue fluid. These are usually most distinct in the hair-shaft just at, and above, the mouth of the follicle, a region termed the *formative region of the fusi,* although from a strict developmental standpoint their origin is just above the region of the hair-generative cells of the papilla. However, it is at the formative region of the fusi that they are first seen in their characteristic form. In most cases the fusi are intercellular, though some cortical cells may be observed in which the nucleus, having disintegrated, leaves behind an apparently hollow space, with dispersed granules similar to a fusus.

As the fusi are borne upward with the growing hair-shaft, their tissue fluid disappears, and they become compressed, thin, and are then distinguishable with transmitted light as delicate, fusiform dark streaks (Fig. 1). Only rarely are they of sufficient diameter, in the middle portion of the hair-shaft, to present the appearance of hollow chambers, except under the highest powers of the microscope.

The fusi differ, oftentimes in a rather constant way, in different parts of the same hair-shaft, and to some extent in hair-shafts from different parts of the same head, but they bear their chief relation to the diameters of the hair-shafts in which they occur; as do also, in general, the forms of the cuticular scales and medullas. Very significant, and more helpful to the microscopist in search of the source of hairs of unknown origin, is the fact that these fusi are sometimes characteristic of the hairs in the head of a given individual; sometimes, indeed, so markedly different from others in respect to their form, size, disposition in the cortex, numbers, and the like, as to make them important to consider as elements of at least diagnostic aid where identification of the source is concerned. In this connection they are to be studied together with the other variable elements of the hair-shaft: the cuticular scales, medullas, pigment granules (and their patterns), and diffuse cortical stain. In some cases the fusi alone may serve for identification, as is strikingly true of so-called "ringed hair." To the naked eye ringed-hair appears to be banded like a fish line. The ringed appearance is caused by masses of fusi which occur at regular intervals in the shaft. Not many samples of this ringed, or banded, hair are on record. The sample in the writer's collection was kindly furnished by Dr. Eleanor McMullen of Wells College. In

some head-hairs examined in the writer's laboratory, the fusi were so unusually large and widely spaced as to constitute, it is believed, a trustworthy criterion for personal identification. In this case, hair-shafts from different regions of the same head all showed the presence of these unusual fusi. In some cases the fusi persist almost to the tips of the hair-shafts—another uncommon condition.

Not only do hair-shafts exhibit natural fusi, formed in the manner which has been described, but may also show rifts or ruptures between the keratized cortical cells of the mature hair-shaft, which differ in form from the natural fusi, and which have been termed *fracture fusi.* They make their appearance whenever the hair-shafts have been subjected to pressure sufficient to dissociate the cortical cells within a given region. Various hair-shafts respond variously to these pressures, some shafts showing fracture fusi upon merely the slightest pressure or light blow, whereas others develop fracture fusi only after much rougher treatment. Such fusi are not discoverable except upon microscopic examination of the shafts concerned. They are useful in aiding in determining the kind of usage to which the hair (or the head) had been subjected.

Natural fusi are sometimes difficult to distinguish from elongate cortical pigment granules or chains. In general, however, the fusi are drawn out into slender filamentous forms, and do not end bluntly as do most of the minuter and elongate pigment granules. In specific cases of hit-and-run automobile deaths fragments of human head-hair shafts, found on the fenders or other parts of the car, corresponded in their fusi with the head-hair shafts taken from the heads of the victims. Furthermore the numerous artificial or fracture fusi suggested, by their numbers, forms, sizes, and dispersal within the cortex of the shafts, the type of maltreatment sustained by the hairs at the time of their deposition on the surfaces where they were found. Subsequent studies have been made of artificial or fracture fusi produced in the laboratory in the cortex of hairs which had been subjected to experimental maltreatments.

These studies have lent further strength to the view that the fusi of hair-shafts—both natural and artificial—may become of increasing importance in microscopy for personal identification and as appreciable aids in reconstructing in the mind of the investigator certain previous unwitnessed occurrences.

How is a hair-shaft prepared for microscopic examination? It is difficult to answer this question satisfactorily in a small space, for much depends upon what one is searching for. In general, the hair is washed thoroughly and repeatedly in ether-alcohol or in xylol to remove extraneous greasy matter, placed on a glass slip, covered with a very thin cover glass, and put at once on the stage of the microscope. This procedure will answer for the general examination of the cuticular scales, but much depends on the lighting of the hair and the magnifications used. If it is desired to study the medulla, the hair-shaft must be cleared by immersing it in some oil, such as oil of bergamont, or of paraffin, wintergreen, peppermint, or in xylol. The refractive index of the clearing medium should be about the same as that of the cortex substance of the hair-shaft under examination. If one wishes to study pigment granules and fusi, the highest powers of the microscope must be called into play.

It must not be supposed that one can take a hair-shaft, and, placing it under a microscope, make out all of its structures at one glance. With the higher powers of magnification all the parts of a hair-shaft (even a very fine one) cannot be seen at one focus, because the parts of a hair-shaft lie on and in a cylindrical structure. This is why it is so unsatisfactory to employ photomicrography in hair-study, except to give general impressions at low magnifications, or to call attention to some single element of structure at moderate magnifications. If one could take a moving picture of a hair while the focus of the microscope is travelling down through the hair-shaft cylinder from one side to the other, then one would have a record of what the eye of the microscopist sees as it travels down through the hair by means of the focusing screws of the microscope. Here is an opportunity for some photomicrographical motion-picture enthusiast to exercise his inventive capabilities.

SCIENCE AND SOCIAL WISDOM

By SAMUEL BRODY

The tower of Babel was a part of a plan to penetrate Heaven . . . magnificent . . . but it ended in confusion.—WILLARD H. DOW.

SCIENTIFIC workers are becoming sensitized to the social implications of science, especially in relation to such new, massive social upheavals as global wars, and are wondering what fate may be awaiting humanity if the development and use of scientific war weapons should continue at the present rate. Many processes tend to correct such disturbances, illustrated by the development of ever larger federal groups such as the American United States, the British Commonwealth of Nations, the Russian Soviet Republics, and by the development of ever more extensive communications tending to unite the whole civilized world into one community. The following discussion attempts to formulate this problem of social disturbance and self-correction from the viewpoint of what may be called the theorem of Claude Bernard in biology, analogous to the theorem of Le Chatelier in physical chemistry. Both theorems are concerned with broad factors tending to restore disturbed equilibria, one in biologic, and the other in physical systems.

There are many categories and gradations in tendencies to restore biologic equilibria. One category is physiologic, designated by Cannon as homeostasis; also as wisdom of the body, or physiologic wisdom. Physiologic wisdom is normally automatic. Another category may be termed, by analogy, social homeostasis, or social wisdom, which ranges from the instinctive or automatic behavior level in bee hives to the partly purposive behavior in human societies. As will become evident from the following discussion, there are no sharp dividing lines between the various categories of tendencies to restore favorable biologic equilibria, and functionally, they all, normally, tend to promote the advantageous long-range survival of the individual or species. Advantageous long-range survival is the chief end of biologic wisdom, physiologic or social, automatic or purposive. This is the functional meaning of social wisdom as used in the title of this essay.

The primary concern of this essay is social wisdom in human society, illustrated in particular by the development of science, moral values, religion, and art; all broadly defined from the biologic-evolutionary viewpoint. However, for purposes of general orientation, the first section is devoted largely to a discussion of physiologic homeostasis, or automatic physiologic wisdom, in the sense of Cannon.

The study of homeostasis is the analysis of the factors that maintain an advantageous dynamic steady state in a biologic (Cannon's physiologic) system in the face of conditions that oppose it.

Many examples may be cited to illustrate physiologic homeostasis, the best known of which is homeothermy, the maintenance of a constant body temperature in the face of wide fluctuations in the environmental temperature. The writer happens to be familiar with the temperature conditions in Miles City, Montana, where a government agricultural experiment station is maintained. The temperature there drops during the winter to –30° F; yet cattle, horses, and sheep winter outdoors without apparent harm. The annual environmental temperature fluctuation is 130° F, yet the rectal temperature of the horses, for example, wintering outdoors is constant, at 100° F; the regulation is precise to within 1° F. How does the horse maintain such delicate temperature regulation?

It is generally known that the skin of sweating species, such as humans, is very cool in hot weather. This is because the vaporization of sweat involves great loss of heat, thus cooling the skin. The blood comes to the surface to be cooled by the skin and so the whole body is kept cool. This is the way sweating species as man, horse, mule, and ass keep cool in hot weather. Some slightly sweating species, such as dogs, keep

cool mostly by protruding the highly stretched tongue and panting, that is, blowing air at a rapid rate over the enlarged moist mucous-membrane surfaces, thereby accelerating the rate of water vaporization. Of course, there are other things that occur, or that the dog does, in hot weather to keep cool: the thyroid activity is depressed and therefore the oxidation rate is depressed; the dog keeps out of the direct sun; he refrains from exercising; he wades in pools or streams; he reduces his food intake, and so on. All this constitutes canine physiologic homeostasis or physiological wisdom as regards body temperature regulation in hot weather. Such nonsweating species as swine keep cool with the aid of mud wallows; the moisture from the mud vaporizes and, like vaporizing sweat, keeps the skin cool.

Quite incidentally, mules and asses appear to have higher hot-weather physiologic wisdom than horses because of differences in emotional patterns. The horse, intent on pleasing, may be stimulated to work in hot weather until he drops dead from "heat stroke"; the more independent, "stubborn," mule or ass cannot be so stimulated to overwork. This is the probable explanation of the reputation mules have of withstanding hot weather better than horses. For the same reason, colored folks are said to be able to withstand hot weather better than white folks: the ambitious white man can be stimulated to work in hot weather until he drops dead from heat stroke or heart attack, whereas the colored man, not troubled by whiteman's ambitions, cannot be stimulated to overwork. This temperamental difference in humans may be genetic but is more probably socially conditioned.

On the approach of cold weather the horse develops cold-weather homeostatic mechanisms: he grows a highly insulating, shaggy coat of hair; he increases the thickness of the insulating fat under the skin; when the weather gets quite cold, the superficial blood vessels contract, driving the blood out from the skin, thereby rendering it insulating like a glove; his thyroid becomes more active, thereby accelerating the oxidation processes in the body; he consumes great quantities of "heating" feed (poor hay, relatively useless for productive purposes, is excellent for keeping the animal warm because it has a high "dynamic effect," like a beefsteak in the human diet, which is excellent to keep one warm in a cold environment). The horse does other things to keep warm: he keeps out of the wind, seeks shelter, seeks the direct sun's rays; he resorts to social-temperature regulation by huddling together with other horses, and so on. The neuroendocrine system synchronizes the innumerable bodily temperature-regulating mechanisms with the outdoor temperature.

While the horse grows his winter coat of heavy hair, his master almost as automatically, but on a different mental level, puts on his sheepskin and other winter clothing to supplement the purely physiologic protectives against cold.

Another well-known illustration of homeostasis relates to oxygen and acid level regulation. The process of living involves the consumption of enormous quantities of oxygen and production of equivalent quantities of acids (carbonic, sulfuric, phosphoric, uric, and so on). Yet the levels of oxygen and acid in the cellular environment remain constant even during exercise when the oxygen consumption and acid production may increase to twentyfold the resting level. This constancy of the intimate cellular environment in the face of environmental change is brought about by many mechanisms ranging from increasing the rates of ventilation and circulation to increasing the concentration of hemoglobin in blood. The hemoglobin may be increased by its liberation from the spleen and liver depots or, if there is time, by acclimatization mechanisms which not only increase the rate of hemoglobin production but also change the hemoglobin composition so that it can carry more oxygen per unit weight.

A less well-known illustration relates to the effect of hormone administration or hormone-gland removal. If thyroid hormone is administered to a normal animal, the animal may, nevertheless, maintain the normal metabolic level by depressing its own thyroxin production. If the sex hormone estrogen is injected, the animal nevertheless maintains a normal level of sex activity by re-

ducing the production of its own estrogen and by increasing the rate of its elimination.

When an animal is excited and ready for a fight, sugar is automatically (under the influence of the pituitary and adrenal glands) poured into the blood to furnish the energy for the forthcoming fight; if the fight does not materialize on a physical plane (as in the case of a spectator at a football game, who does not himself fight although emotionally geared thereto), the sugar is eliminated by the kidney, constituting the well-known phenomenon of emotional glycosuria, thus keeping the blood-sugar level constant.

A certain disease of the adrenal gland is associated with extreme loss of common salt; the animal automatically (under the influence of the taste-hunger mechanisms) compensates this salt loss by consuming enormous quantities of salt. Indeed, extreme salt consumption is often a diagnostic symptom of such adrenal disease. Similarly, removal of the parathyroid gland (which regulates calcium metabolism) is associated with a craving for, and fourfold consumption of, calcium, and conversely an unusual craving for bone or earth may indicate parathyroid abnormality. Appetite is, under natural conditions, frequently a good guide to nutritional wisdom. For instance, herbivorous animals, such as cattle and squirrels, do not normally consume animal products, yet they relish bones during gestation and lactation when there is an extra demand for calcium. The hunger mechanism is complemented by other devices. Thus heavy lactation with its high demand on the blood calcium enlarges the parathyroid gland to enable it to draw on the skeleton calcium, thus supplementing the dietary calcium.

A spectacular homeostatic example is furnished by the regeneration of limbs in lower animals (recall the experiment of removing the tail of a tadpole and watching the regeneration of the tail to its "normal" length) and in healing of wounds in higher animals. Some types of healing, as that of tongue or gum, occur in the course of minutes or hours, especially if one is young.

Incidentally, aging is associated with decline of homeostatic function; aging is, indeed, best measured not by the number of years lived but by the ability to maintain constant the internal environment, such as the internal body temperature or the internal level of the oxygen, in the face of a rapidly changing corresponding factor in the environment. Chronic disease and death are associated with the results of failure of homeostatic function. The immediate cause of death is normally a breakdown of homeostatic function, inability to restore to normal a seriously disturbed condition; for example, the inability of healing a wound, inability to maintain body temperature constant (fever), or inability to overcome an infection. The system disintegrates, dies, if the homeostatic ability is lost; and what is true for an individual appears to be true of some animal societies.

The problem of physiologic homeostasis may, perhaps, be viewed from what has been termed the organismic, or field, theory in biology, similar in intent to the field theory in physics. Just as the field in physics may be conceived to be a physical (an electromagnetic) integrative process, so the field in biology may be conceived to be an integrative biologic process binding many components into a whole and tending to be restored on disturbance, which is one definition of homeostasis, the tendency to be restored to normal on disturbance. The organismic viewpoint leads to the inference that in the struggle for survival in the course of evolution the component parts of the body had to develop so as to function in symphonic harmony of an optimal pattern. An organism is a closely-knit community, the component members of which—nervous, endocrine, circulatory, excretory, digestive, and so on—co-operate in maintaining a dynamic steady state in the face of fluctuating external conditions. This is essentially Claude Bernard's generalization in modern language.

There is no sharp dividing line between physiologic and social, instinctively-automatic and conscious homeostasis, or wisdom.

For instance, the reproductive function attains peak activity when growth approaches its end, that is, when the individual organism begins to get old. The lawn grass goes to seed most readily when individual

life is threatened or is on the decline (as in drought, etc.). Reproduction of the individual may be viewed as a social homeostatic mechanism. By reproduction the "internal environment" of the social organism is kept constant in spite of the aging and dying of its constituent members. Incidentally, only human beings survive for long periods following cessation of the reproductive function; this may be an important condition for developing disinterested wisdom.

The reproductive process is extremely complex and, needless to say, the reproductive drive tends to be satisfied whether or not the individual animal foresees its sociocentric purpose; just as hunger and thirst drives are satisfied whether or not one foresees their ultimate aim. In either case the ultimate functional aim appears to be to maintain constant what Claude Bernard termed the internal environment of the organism, individual and social.

The homeostatic mechanisms tend to evolve to ever higher or finer organizational levels. For instance, the most evolved animals, the mammals, do not drop their eggs in the ocean as fish do, but house and nurture the young in an especially evolved body cavity, the uterus; then after birth the mother gradually bridges the young to the independent mature life by warming it, cleansing it, and feeding it with a special food, milk, elaborated by the mammary gland. The development of the mammary gland is synchronized with the development of the reproductive organs, and the activity of the gland in milk production is synchronized with the dietary needs of the young. This perfect synchronization is brought about by complex neuroendocrine mechanisms.

Incidentally, man learned to expand this natural lactation function in dairy cattle to unnaturally, fabulously high levels, for his own rather than the calves' benefit. Dairy cows have been developed to produce some fifty quarts of milk a day, every day for 365 days, completely out of the range of the need of a growing calf. This example illustrates the plasticity, adaptability, and potential range of homeostatic functions. The homeostatic function may be, so to speak, misled or stimulated to act outside the range of biologic usefulness and indeed to the detriment or even destruction of the organism. This is an important biologic fact from our viewpoint.

Another example of adaptability and plasticity of homeostatic function relates to the time of sex mating. Species that evolved and are living in regions with wide seasonal temperature fluctuations confine their breeding activity to a sharply limited interval of the year. The time of breeding depends on the length of the gestation period; mating occurs only at such time of the year as will give the newborn animal the highest probability for survival. Shifting of the animal to another latitude changes correspondingly the breeding date. Shifting the animal to the tropics where fluctuations in temperature, light, and food-supply are insignificant, or domesticating it so that its food supply, warmth, and light are uniform throughout the year, often abolishes the seasonal breeding rhythm. Thus, whereas wild cattle breed in the autumn only, domesticated cattle breed throughout the year. Whereas wild fowls produce only one batch of perhaps a half dozen or dozen eggs in the spring, domestic fowls may produce eggs throughout the year, often 300 or even 365 eggs a year. The internal biological controlling mechanism of the seasonal breeding rhythm resides in the anterior pituitary body (at the base of the brain); the external controlling agent is usually sunlight (ratio of day to night length), and the external stimulus is usually carried to the internal control by way of the optic nerve (the eye). This mechanism is definite but plastic, modifiable, educable, so to speak, to act differently under changed conditions.

The intimacy of the mammalian type of reproduction develops family life. Family life is also strong in many birds, especially in those, like pigeons, which produce "crop milk," and on a different organizational level, in social insects. But it is perhaps on the highest level in mammals, and particularly in man, distinguished from other mammals by a higher level of consciousness and by raising children of different ages simultaneously, thus evolving a special type of

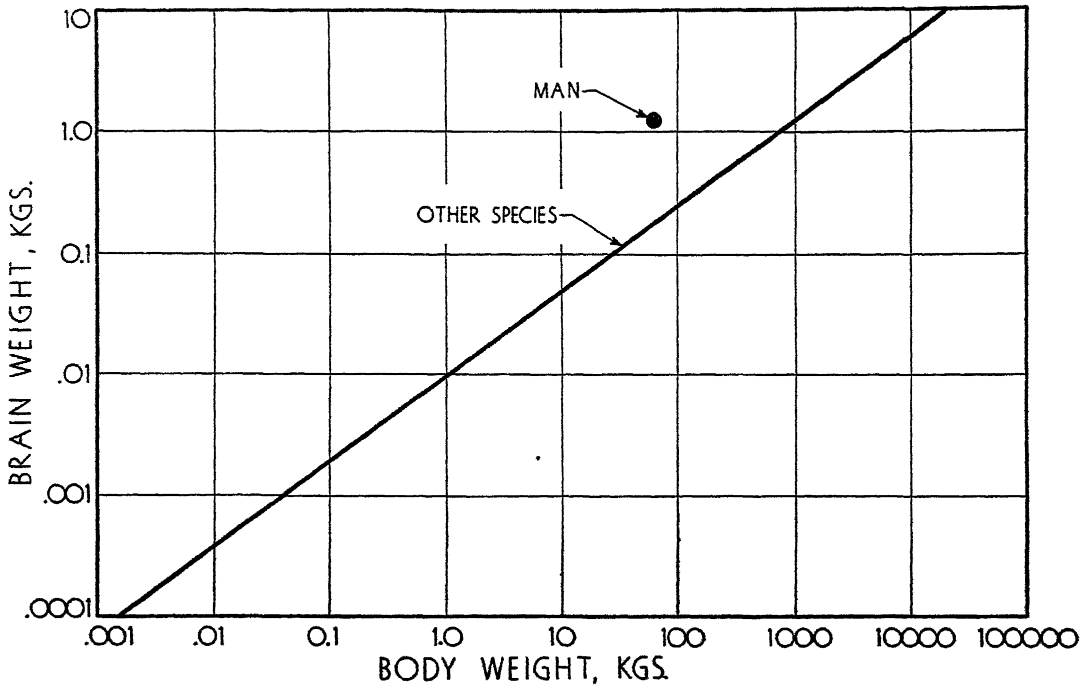


FIG. 1. RELATION OF BRAIN WEIGHT AND BODY WEIGHT IN MATURE MAMMALS
THE DIAGONAL LINE SHOWS HOW AVERAGE BRAIN WEIGHT OF NONANTHROPOID MAMMALS IS CORRELTED WITH THEIR AVERAGE BODY WEIGHT. THE AVERAGE WEIGHT OF MAN'S BRAIN (BLACK DOT) IS EXCEPTIONALLY HIGH.

social life between individuals of different age and strength and leading to the development of the uniquely human social characteristic of patience, forbearance, and charity on the part of the older and stronger children towards the younger and weaker. This is, perhaps, the biologic origin of morals, ethics, and religion.

In man we see the family idea, with its higher level of conscious regulation, or homeostasis, develop into ever larger aggregations—tribe, clan, nation, and ultimately, perhaps, supranation. These broader human aggregations are made possible by the unique human ability for abstract thinking and communication in symbolic terms—language. By such communication man learned to recognize, in an impersonal way, the relatedness of all men. These unique recognition qualities in man have a structural basis in his nervous system. Primitive animals and primitive functions in higher animals are controlled by the autonomic nervous system concerned primarily with adjustment between organs within the individual; the higher functions in the more evolved animals are controlled by the central nervous system, especially by the brain and more particularly by the forebrain or the cerebral cortex, concerned with adjustment of the organism as a whole to distant environment. The development of the brain reached enormous proportions in man with correspondingly far-reaching recognition qualities. The brain weight (by no means the only index of high development) in 150-pound man is 3 pounds, whereas that in 150-pound sheep is only ¼ pound and in 1500-pound cattle it is one pound (Fig. 1). Indeed, with the exception of whale and elephant, man has the largest brain of any species.

The above discussion indicates the presence of many categories of homeostasis or wisdom, ranging from automatic physiologic processes and, perhaps, completely automatic social behavior in some social insects, to the relatively unpredictable social behavior of higher birds and mammals and particularly

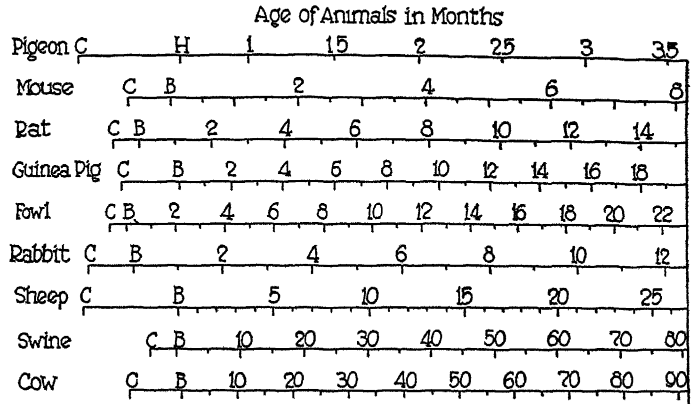
of man. The difference between these various categories is one of degree, that is, quantitative rather than qualitative. Man, for example, has the same physiologic functions and emotional drives as other mammals although his cerebral activities, his mental powers, function on a higher level.

These differences in level of mental activity and in predictability, of course, have important implications. Human behavior is relatively indeterminate and unpredictable, which makes it difficult to develop a science of human social behavior as it is possible to develop a science of physiological behavior or a science of insect social behavior. On the other hand, the relative unpredictability of human social behavior, which is the despair of the social scientist, offers man an opportunity to mold human behavior, and even to mold destiny, which is not given to other species; it gives a biologic basis to the biblical assertion that "The Kingdom of Heaven is within you," and it poses the problem of how to develop a social wisdom to translate this potentiality into reality.

Human social wisdom differs especially from subhuman wisdom in that human social behavior on the exclusively human level is conditioned by tradition, by an ever-growing body of experience. Let us define the elements of social wisdom on the uniquely human level—definitions that may indicate their functions.

The elements of social wisdom on the uniquely human level are, in the writer's opinion, objective knowledge of natural phenomena represented by science and the subjective attitude to the universe, especially to humanity, typified by religion and art.

Science and religion are interrelated in that both represent man's tendency to generalize what appear to be important phenomena. Our biblical cosmology may, from



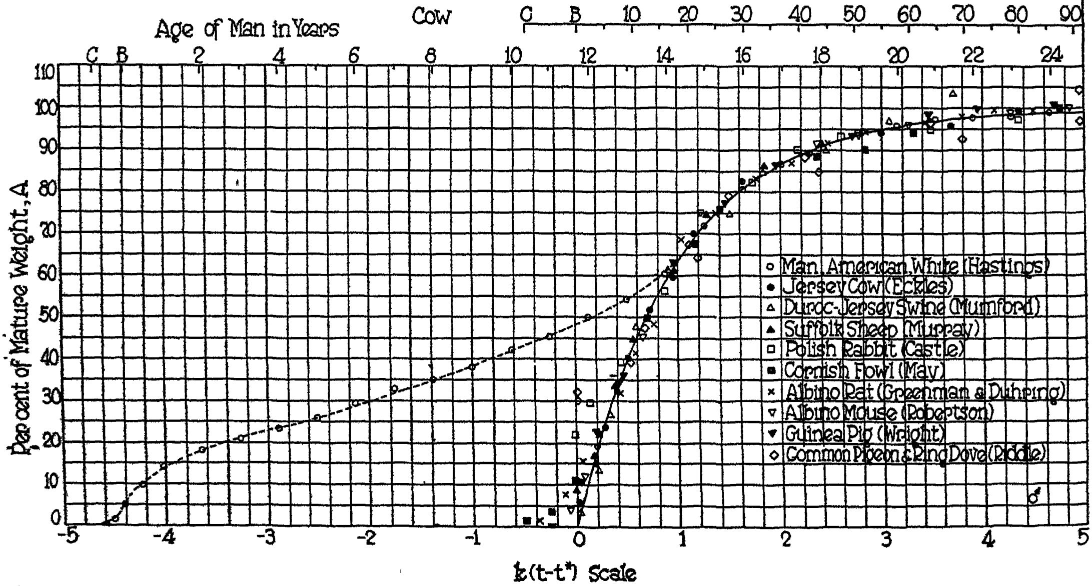


FIG. 2. AGE CURVES OF GROWTH IN WEIGHT IN MAN AND OTHER SPECIES
ILLUSTRATING THE PECULIARLY SLOW GROWTH OF MAN. C = CONCEPTION, H = HATCHING, B = BIRTH.

this particular viewpoint, be considered to have been the science of the age when the Bible was written; and our modern cosmology may in turn be said to have evolved, in part, from our biblical cosmology. The fact that the biblical cosmology is outmoded is not a valid argument against this viewpoint since science is continually changing and some present theories, in the younger sciences at any rate, may in turn be outmoded.

Science and religion are also interrelated in that both have their biologic origin in the highly developed human brain (Fig. 1), in the peculiarly slow human growth rate (Fig. 2) (the prepubertal percentage growth rate of sheep and goats, which have the same mature weight as man, is sixtyfold that of man), in the relatively very long human life span (about sevenfold that of subhuman mammals of the same mature weight), and in the possession of the mechanisms of speech and writing.

The large and highly developed brain affords reflective power and furnishes the basis for speech and writing, the long growth period affords opportunity to learn, and the long life span affords time to reflect and to develop traditions, all of which are prerequisite for the development of religion and science. Moreover, the long human childhood period of dependency on parents stimulates socialization, the rearing of children of different ages simultaneously (a uniquely human characteristic) reinforces socialization with charity and tolerance on the part of the stronger to the weaker children, and the mental consciousness of the involved relationships lead to the development of group morals. This combination of circumstances was associated with the evolution of symbolic, abstract, and conceptual methods of thinking and transmitting knowledge, especially to successive generations, and consequently led to a new method of biologic evolution depending on social inheritance of knowledge rather than on changing the genetic constitution of man.

With this background in mind we proceed to define science, moral values, religion, and art, the elements of wisdom on the exclusively human level.

Science is concerned with the description and logical organization of objective, independently verifiable observations. Scientific knowledge is photographically literal, emotionally and morally neutral, allowing only for relativity effects.

This definition represents only the objective and the amoral aspects of science. Science has other aspects, of course; it has high spiritual, moral, and aesthetic values also, as that of bringing out the beauty, the unity, the "wisdom," and the "moral order" of the universe. But from the viewpoint of social wisdom on a human level, it appears simplest to view science from the morally neutral viewpoint; and as such, scientific knowledge may be compared, for example, to morally neutral fire, which may be used for warming and cheering or for burning and hurting, and it is so used for both. For example, scientific knowledge has been employed to raise health, longevity, material comforts, intellectual and spiritual satisfactions (travel, radio communication and music, insights into laws of nature) to the highest level in history, and it has also been used to raise the destructive power of war and the social confusion to the highest level in history. Scientific knowledge is growing rapidly and so is its potentiality for construction and destruction.

Moral values may be considered from several functional or operational viewpoints.

From the religious viewpoint moral behavior is judged by its effects on human life. Jesus said, "By their fruit ye shall know them," and all great historic religions, that is, those that survived long periods, have the Golden Rule as a common element. This is indicated by the following quotations: Jesus said, "All things ye would that men should do unto you, even so do ye also unto them." Rabbi Hillel (Jesus' contemporary) said, "What is hateful unto thee do not do unto thy fellow." Plato (427–347 B. C.) said, "It is worse to inflict wrong than to suffer it." Confucius (551–478 B. C.) said, "What you do not want done to yourself, do not do unto others." An Egyptian code of 5300 years ago states: "Life is given to the peaceful and death to the criminal." Recently F. R. Moulton proposed a code of international ethics on the same

principle: "Each of the signatories hereto agrees to ask for and accept from the other contracting party only such privileges, rights, and commitments as it will offer to the other party."

The Golden Rule appears to have a sound evolutionary-biological basis because, as S. J. Holmes remarked, although people ascribe the origin of their codes to the commands of their gods, the true cause for their development is their survival value.

From the Darwinian or evolutionary-biologic viewpoint, the criterion of "moral behavior" is advantageous long-range survival of the species. Moral behavior is thus socially beneficial behavior, and moral values are socially beneficial values.

We have already defined social wisdom or social homeostasis as behavioral reactions which promote social survival. It is thus evident that while moral values, social homeostasis, and religion are not identical concepts, they are functionally related; they are all concerned with the advantageous long-range survival of man. Advantageous long-range survival is the criterion of wisdom, physiologic or social, automatic or purposive.

There are those, like Arthur Schopenhauer, who deny, on philosophic grounds, the desirability of the survival of man but, as aforenoted, this discussion is from the evolutionary-biological viewpoint only.

Religion is more intricate than science or moral values because religion is the parent of science and moral values and of many other concepts, real and imaginary, mental and emotional, and traditional religion is, therefore, cluttered with many vestigial parts, meaningful in the past but confusing and troublesome in the present.

Present-day religion, as conceived by the writer, is concerned not with cosmology or science as such but with the purpose for which scientific knowledge should be used, with the attitude of man to mankind and the universe. As aforenoted, the great historic religions have the Golden Rule as their moral basis, and while not always easy to interpret under practical conditions, this seems to be the best available guide for the moral conduct of life if judged by functional criteria "by their fruit ye shall know them." So much for the moral aspect of religion, which has a high social-wisdom value.

From the other, spiritual, viewpoint religion is a groping for integrated living, for a unified life purpose, for "the chief end of man"; it is a philosophy of the meaning of life, its frustrations, tragedies, and spiritual experiences, usually involving communion with a "supreme reality."

The nature of the spiritual reality, deity, or divinity is not, however, generally accepted as is a given scientific reality, but varies among groups and individuals ranging from an anthropomorphic entity extending the gift of eternal salvation to his devoted worshippers and the "punishment of eternal damnation for the sinners" (Jonathan Edwards) to an abstraction expressed in various ways: a poetic mystic spirit; "God as the incarnation of the moral ideal of mankind, the perfection for which man strives" (J. W. Hudson); a consecrated value; a "Devout and Contented Uncertainty" (Roger Williams); the recognition of the "Seed of Divinity in Every Human Breast" (William Ellery Channing); "The Personification of All That Is Best" (W. C. Allee); the sacredness of scientific progress in promoting human welfare, or "Scientific Humanism" (J. Huxley); the "Contemplation of the Beauty of Holiness" (A. N. Whitehead), and so on.

From many viewpoints religious revelations, attitudes, and realities are analogous to, if not identical with, certain artistic revelations and realities; the exaltation or spiritual satisfaction derived from the contemplation of the sacred seems, however, to transcend for most individuals those derived from the contemplation of the secular (art, science, nature). However, a slight change in view or in conditioning of attitude may transfigure the secular into sacred. Thus the practice of the Golden Rule could be transformed into sacred ritual.

An important aspect of institutionalized or conventional religious creeds and rituals is that they are rarely accepted by adults who were not conditioned to them in childhood, and a child can be conditioned with equal ease to any religious faith. This is the basis of religious and sectarian quarrels,

a potent cause of irrational friction and even war. This is an imporant difference between religious beliefs and scientific knowledge: whereas the scientific law of gravitation, for example, is generally accepted, a given religious doctrine or ritual is usually accepted only by those conditioned or indoctrinated in childhood. Hence one speaks of scientific knowledge but of religious creed, doctrine, or feeling, which vary with individual vision, environment, and background.

As aforenoted, the biologic-evolutionary, including the homeostatic, viewpoint is concerned with advantageous long-range survival of the species. This preoccupation with the advantageous long-range survival of the species may, figuratively, be designated as the biologic religion or moral code. But religion likewise appears to be preoccupied with the advantageous survival of humanity. This is indicated not only by the religious tradition of immortality but especially and much more significantly by the recognition of ever wider human kinship, as indicated, for example, by the Christian-Hebraic monotheistic doctrine of one God, one Father, and the brotherhood of man. Biologic, including homeostatic, and religious aims thus appear to converge, indeed to coincide, at their limits. Religion, indeed, appears to be a biologic-homeostatic phenomenon. A biologist may, therefore, define religion to include both the biologic and the limiting traditional-religious viewpoints, thus: *Religion is the consecrated devotion to the values and/or to the faiths* (that may or may not be mystic and/or theistic) *which seem to promote the best interests of humanity.*

This definition or interpretation of religion has many practical implications.

First, this definition eliminates the so-called conflict between science and religion. Religion is represented as an attitude promoting the advantageous long-range survival of humanity, and leaves to the individual whether or not this attitude should be mystic and/or theistic in spirit.

Second, this definition of religion based on the Golden Rule and on the devotion to values which seem to promote the best interest of humanity is, so to speak, Basic Religion, a common element possessed jointly by all healthy religions. The wide appreciation that Basic Religion as above defined is a common element possessed jointly by all healthy religions should eliminate the confusion, social friction, international misunderstandings, and wars associated with the attitude of those who regard other groups as heathen or pagan.

Third, the above interpretation of religion as including all of humanity is definitely opposed to the rationalization of racial wars, riots, and persecutions. While there are extremely wide individual and family differences within every living group (no two leaves on the same tree have precisely the same structural pattern), the most eminent biologists and anthropologists free from prejudicial conditioning and from the influence of pressure groups doubt the existence of biologic and/or humanly essential differences due to race as such, at least among the civilized peoples. Social and other environmental conditioning appear to exert a much greater effect on the behavior of the average member of a racial group than his genetically racial constitution. Quoting Redfield, "Race is a variable that depends upon custom and changes with historical event. It is not the actual but the believed-in difference of race that is of consequence and is darkened by propaganda. Political and sectarian movements seize upon racial issues for their power to align men against each other."

Race persecutions, that is persecution of minorities, may be an expression of a primitive animal drive for self-aggrandzement by persecuting the defenseless, as indicated by W. C. Allee's studies on the "pecking order" in chickens, mice, and other animal societies; and/or expressions of escape rationalizations, shifting of responsibility for one's frustrations, which is another form of self-aggrandizement.

The race problem which needs clarification on scientific and educational levels does not offer complications on the religious and moral levels.

Normally the biological reaction to an unfavorable factor is to overcome it by some

device, as by sweating in hot weather or by developing warm covering in cold weather. Some reactions, however, tend to run in a vicious circle. For instance, in unchecked fever the higher the temperature, the higher the rate of oxidation or heat production (law of van't Hoff and Arrhenius), and the higher the rate of heat production, the higher the body temperature. This is also the effect of external high temperature on non-sweating species, such as swine, that have no access to cooling devices such as mud wallows. The course tends to run in a vicious circle terminating in death of the individual from overheating.

There are probably similar vicious-circle phenomena in evolution. For instance, large size is a favorable factor for the survival of a young animal competing with its litter mates for food. Large body size may also be a favorable factor for a polygamous animal in his competition for a female. The result is that successive generations may inherit ever larger body size, with the ultimate development of races of giants, such as dinosaurs. The giant body size, however, probably led to the extinction of the species because large size is an unfavorable factor in search for food and in withstanding high temperature.

Sharp teeth are normally advantageous to predaceous species, such as tigers, and sharpness of teeth may run in a vicious circle. The saber-toothed tiger was so successful in developing his hunting teeth that he became the dominant species. But after obtaining this position of dominance for the species, the teeth were probably employed for improving dominance of individuals within the species. In this way the individuals with the most formidable saber-teeth alone succeeded in reproducing themselves, and this tendency assumed a vicious circle: the development of ever more and more formidable teeth could not be stopped, and the fighting became ever more dangerous, which may have led to extinction of the species.

The precise factors that led to the extinction of the saber-toothed tiger cannot, of course, be scientifically determined, since they occurred in ages past. But the above explanation, based on the appearance of fossil specimens locked by their saber teeth, seems reasonable and illustrates in dramatic manner how seeming success may hold the seed of failure. The earth's layers are replete with fossils of highly evolved species which rose to prominence and declined to extinction. Even the brief era of written history, five or six thousand years, witnessed the rise and decline of human civilizations and animal societies, and some of the declines may have been caused by some such vicious-circle phenomena as were assumed for the saber-toothed tiger or for the dinosaur.

The story of the saber-toothed tiger recalls the contemporary crisis in the evolution of humanity. Man appears to be a social fighting animal who began his fighting career with his limbs, then developed the intricate technique of throwing missils, such as stones, then shooting arrows, using swords and armor, then bullets. The effects of such warfare were relatively local although these small developments managed virtually to wipe out civilizations and probably, by killing off many physically able, to reduce the stature of many peoples, as that of the French by the Napoleonic wars.

But now, with the growth of science and technology, we no longer think of arrows or bullets and local wars, but of blockbusters, rocket guns, and of global wars, destroying and incapacitating millions of persons and wiping out untold material and cultural wealth. We also learned how to use words as war weapons in deadly psychologic warfare to frustrate and to stir up hates and fears on ever wider scales. The question naturally comes to mind whether fighting man will follow the path of the saber-toothed tiger towards extinction as the result of overdeveloped weapons? Will war casualties rise in geometric progression (30 million in World War I, 60 million in War II, 120 million in War III, etc.) until the species will have become incapacitated? Will our tower of Babel lead to confusion and exhaustion?

The above question brings into sharp relief the central problem of this essay; namely, the nature of the social homeostatic or

social-wisdom mechanisms of the species *Homo sapiens*, modern man, known in his present physical form at least 50,000 years. Has he now entered the vicious-circle era? If so, will the fact that man operates on a high level of consciousness enable him to redirect or break up in a conscious, purposive manner this vicious-circle type of development? Will social scientists discover methods for aiding the social-wisdom forces in healing the ailing human society in its present evolutionary crisis as medical scientists discovered methods for aiding the physiologic-wisdom forces in healing an ailing body in its life crisis?

Man appears to be a social-fighting animal. As pointed out by Allee, Gerard, and others, the evolution of social-fighting animals involves a balance between two opposing yet interrelated drives: a) egocentric or egoistic, exemplified by the struggle for self-aggrandizement, for a dominating position in the social hierarchy; b) sociocentric or altruistic, exemplified by loyalty to the family, flock, herd, pack, or in man to family, gang, tribe, clan, nation, and perhaps eventually to humanity. There is no sharp dividing line between the two. Thus in human society individual development is egocentric yet socially beneficial, and indeed such concepts as democracy, *laissez-faire,* and Christian salvation stress individual development in the interest of society. War itself involves both of these drives.

Examples of human sociocentric drives were illustrated especially by the human method of rearing children of different ages and strength simultaneously, by man's various categories of loyalties and by the definitions of religion and moral values. One might also add to the sociocentric humanizing forces a new one, the influence of modern science, which operates disinterestedly on a world-wide basis.

For illustrations of the egocentric drive, it is sufficient to note that man hunts other species and even other human "races" for the sheer pleasure of the hunt, insensitive to and, judging by recent war atrocities, perhaps pleased by the pains he inflicts; he wars with other groups within his race and quarrels and fights with members of his own group. Man has a good brain, uses it for devising ever more destructive weapons, although being rational and noble, he devises plausible, justifying reasons for irrational and ignoble fighting. Man invents and commercializes methods for blowing human beings to bits and uses the profits therefrom for building hospitals. Man has developed an extraordinary genius for getting himself into unnecessary trouble under the influence of the two opposing drives.

Paralleling and counteracting the development of man's increasing destructive powers which have been used to aid his pugnacious and self-aggrandizement drives, there has also evolved, in virtually all human cultures and under all conditions, a unique altruistic and integrative power, religion, with its basic elements of humility (the consciousness of a higher power than man, however defined) counteracting the pugnacious and self-aggrandizement drives, and "goodness" (illustrated by the Christian-Hebraic doctrine of human brotherhood and the Golden Rule) counteracting the wolfish fighting drives.

Thus viewed, religion, in a broad sense, acted as a stabilizing, social-homeostatic, social-wisdom, or social-survival influence in the face of developing combative weapons.

But the stabilizing or homeostatic function of evolutionary or traditional religion couched in the anthropomorphic and supernatural terminology of another day is weakening under present conditions.

While, as here defined, there is no conflict between modern science and religion—one is concerned with objective knowledge, the other with an attitude towards mankind and the universe—institutional, traditional religion does contain much that is irrelevant, and the questioning, critical, analytic spirit of science, which insists on ever more concrete evidence, tends to erode the authoritarian and irrelevant doctrines and ritual. Moreover, the encounter of contradictory religious opinions and practices, as a result of the development of rapid communication, urbanization, and migration which commingles persons of widely different religious viewpoints, blurs old religious traditions. The decline of traditions, the social-evolu-

tionary *moral carriers,* weakens the influence of the interrelated traditional *moral values,* thus tending to remove the inhibitions to the egocentric drives. The situation is, moreover, complicated by radical technologic innovations which led to technological unemployment and destitution in the midst of potential plenty with consequent frustration and irrational class, race, national, and other escape hates and strife, and finally to global wars.

The developments of science and technology, good in themselves, thus seem to have upset social-evolutionary equilibria between the egocentric and sociocentric forces, the balance between the power conferred by amoral knowledge on one hand and by the social-evolutionary, social-wisdom, or moral carriers on the other. Moreover, the greater the power of the amoral technological knowledge, the more dangerous it becomes if its use is not guided by social wisdom.

The result of the disharmony between the older religious or social-wisdom formulations and the new scientific-technologic age may be illustrated by the rise of the new German ideology. The apparent enthusiasm for it, as it appeared to the author during a sojourn in Germany in 1931, was in no small part due to a growing spiritual need for an integrating faith. This need was capitalized by little men making big promises in pseudoscientific and pseudoreligious language. Men must have an integrating faith, and having lost their traditional deity and theology, they developed a new one, one that appears to lead to the vicious-circle pattern of evolution.

A major social-homeostatic need, then, seems to be to bring together science (organized factual knowledge, which is morally neutral) and religion and moral values in the sense of social wisdom as here defined. Since religionists do not appear to be able to bring about this situation, it would seem that scientists, who now appear to command greater confidence and prestige than professional religionists or statesmen, and who are, in a sense, responsible for the disturbed evolutionary equilibrium between the effects of sociocentric and egocentric drives, should assume indirect social and religious leadership in this critical situation in promoting progress in creative religion (broadly defined as socal wisdom) so that it will parallel the progress in creative science.

It is suggested that the representative bodies of scientists attempt to define and predict in scientific spirit and in simple language (perhaps by forums, symposia, and popular books on social wisdom) the ideals and the evolutionary trends of *Homo sapiens* and suggest strategy for avoiding perils, especially of the vicious-circle type, and for attaining the seemingly ideal objectives. Special attention should be given to defining and placing the problem and applications of religion on a universal basis, emphasizing the social-wisdom (in contrast to supernatural) functions of religion and thus minimizing religious and denominational frictions and wars. Social technologists, especially practical religious leaders, should similarly, in co-operation with psychologists, attempt to devise religious ritual on broad principles common to all historic religions, and based on scientific knowledge, for attaining the state that we think ought to be. The preparation of a compact social-wisdom guide or code and its annual revision in the light of new developments (so as to avoid fixation of the guide into a creed or dogma) with the accompanying publicity, may contribute greatly toward helping mankind to clarify the meaning of life and to avoid catastrophy. There could then be said of science what Jesus said of Moses' Laws: "I came not to destroy the Law but to fulfill it."

BIOTREPY—THE GOOSE OF THE GOLDEN EGGS

By PAUL D. LAMSON

AFTER a cycle of some seven thousand years we are back where we started. We believe once more in "drugs." Everyone is scrambling for these golden eggs but there is a great difference of opinion as to what breed of goose lays them. The pharmacologist, the chemist, the pharmacist, those in various branches of industry and government, and more than a few in woodsheds and kitchens are convinced that they can conjure up eggs of gold. That these eggs are of pure gold, there is no longer any doubt. Even the patient can testify to this with a clear conscience and without bribery. Drugs are not used in therapy alone; investigators in all branches of medicine, whether anatomists, physiologists, biochemists, pathologists, or clinicians, know that chemical substances are often the best tools for their experimental work. The search for these golden eggs is therefore a problem of interest to all in medicine, chemistry, and industry, and to the general public as well. In the present rush for these magical eggs the goose that lays them has been sadly overlooked and almost no thought paid to the raising of goslings. We would do well not to repeat the error of the past and kill the goose. It is the object of this article to point out that a special breed is necessary for the laying of such eggs.

This article is not written, however, for the purpose of singing the praises of pharmacology, which has been a useful stepping stone in medical progress, but to suggest that it be replaced by a medical discipline better suited to our needs.

We seem to have overlooked the fact that the study of drugs is chemistry, which is not a biological subject. The "action" of drugs is still chemistry as the only action a drug can have is due to its chemical and physical properties. Its primary "action" in the body is chemical or physical but, except in rare instances, we cannot discover what this is. We have no idea what the chemical reactions of strychnine or morphine in the body are. We do know in certain cases, as that of sodium oxalate, that this substance reacts with the calcium of the blood and forms insoluble calcium oxalate. There is nothing peculiar in this "action" of sodium oxalate in the body; it is exactly the same there as elsewhere. If we could tell the chemist with what substance in the organism strychnine reacts, he would be able to tell us in all likelihood what the reaction would be; he may even know this reaction now. But knowing either of these reactions does not tell those who do not understand the organism that sodium oxalate will prevent blood from clotting, that morphine will make the pupils constrict, a dog vomit, a Fiji Islander go wild, and a white man go to sleep. These are not "actions" of morphine; they are "reactions" of the organism. They are all physiological reactions secondary to the primary chemical one between chemical substances in the tissues and the "drug" introduced.

In medicine we are studying the human organism, a branch of biology. We study this organism as the chemist does his chemical substances; that is, by means of its *reactions*. The days of studying the organism in a static condition are passed. Gross and microscopic studies of the normal and pathological organism are fairly well completed and much has been accomplished in the chemical analysis of tissues. Now everyone is studying the reaction of the organism to stimuli of different sorts. Electricity and disease have been the two great classes of stimuli most used in the past. It is only more or less recently that we have come to realize the opportunities that we have for studying the organism by means of its reaction to chemical substances. Here we have almost a million tools. We can choose one to fit our needs and reshape it as a locksmith would a key. There is practically no limit to the tools that we might make. Through such studies we shall not only learn more about the functions of the body, but we shall obtain the means of bringing about desired reactions in disease.

I have suggested in previous publications that we give up pharmacology—which after

all is pharmacy, even in name—and replace it in our schools of medicine by a biological science which would emphasize *the study of the reaction of the organism to chemical substances rather than of the drugs themselves.* Let us consider why such a suggestion is made. It is not done simply to upset a well-established medical discipline, as it will be shown that pharmacology as such is not well established. The study of drugs in medicine has been a bone of contention for generations. First, under the heading of pharmacy, everything imaginable was given to patients without previous trial in animals. Over several thousand years many useful drugs were found by this method of trial and error, but such a high percentage of these substances were of no value that a period of therapeutic nihilism set in. For a long time there was no special group studying drugs in our schools of medicine. A great mass of facts and fancy was taught under the heading of "materia medica" by anyone willing to undertake the task. In 1850, Rudolf Bucheim, a great scholar and a good chemist, physiologist, and clinician, attempted to bring order out of the then-existing chaos by studying the "action of drugs" in animals, discarding the useless ones and arranging the others systematically according to their chemical nature. For this medical discipline he used the name pharmacology, an old synonym for pharmacy, but the failure of this plan can be seen in a single illustration taken from Bucheim's book. Under the heading, "Sodium Sulphate," a heterogeneous group of chemical substances were brought together:

VIII. *Gruppe des Glaubersalzes*
Glaubersalz
Bittersalz
Schwefelsaures Kalium
Phosphorsaures Natrium
Weinsaures Kalium
Seignettesalz
Abfuhrendes Brausepulver
Boraxweinstein
Aethylschwefelsaures Natrium
Doppelt kohlensaures Magnesium
Citronensaures Magnesium
Mannit, Manna, Mannasyrup

The only reason for their being put in such a group was that these substances had the common biological property of causing the body to react by catharsis.

A strictly chemical arrangement of drugs is of no value to a medical man, as can be seen if one takes any list of chemical substances, as the alphabetical one in the index of Dyson's, *The Chemistry of Chemotherapy.* No one can use such a list for medical purposes unless he already knows what he goes to the list to find.

α: α′-Dichloroisopropyl alcohol carbamic ester
3: 5-Dichlorophenyl arsonic acid
3: 8-Diethoxy-9-carboxylic acid
Diethylacetamide
Diethylaminoacetonitrile
Diethylaminolactic nitrile
Diethylaminolactic nitrile methyl iodide
Diethylaminophenylacetonitrile

The tables of contents of a series of textbooks in pharmacology show how headings have changed from Bucheim's chemical headings to biological ones, but as yet there is no system or order.

If one studies the reaction of the organism to chemical substances, the critics will say that this is physiology, biochemistry, or pathology, and so it is, but all of us in medicine are doing the same thing and are separated into disciplines merely for the sake of convenience and specialization.

A very practical reason for giving up pharmacology and substituting a different medical discipline is that one cannot become an expert in pharmacology or specialize in any branch of it. One cannot become an expert on a million substances, and one cannot specialize because the study of a single drug involves the reaction of all of the thousands of parts of the organism, and even the most closely related chemical substances may produce utterly different bodily reactions.

If we reverse this and study the body as all others in medicine are doing, we can become experts—specialists on the nervous system, blood, or parasites—but experts of a different sort than those in any other field of medicine.

Space will not allow a discussion of the organization of such a medical discipline, which has been gone into elsewhere, but it might be pointed out that the reaction of the whole organism is the resultant of reactions

of its countless parts. To bring order into such a bewildering system I have suggested that the problem might be approached by systematizing our knowledge around the smallest biological unit of which the body is made, the cell. By studying and classifying reactions under types of tissue, regardless of their location in the body, it would make it possible to orient ourselves readily, as all reactions, no matter how complex, originate in certain cell types. As we are unable to discover exactly what cell types are affected in the greater number of reactions, we shall still have to arrange material under more general headings, but in all cases they will be of a biological rather than a chemical nature, except where we are dealing with single chemical substances within the organism.

A study of the evolution of medicine indicates that a split occurred early between biological and nonbiological subjects. It would seem time to take the last step and rid medicine of the single surviving branch which studies something other than the organism; namely, pharmacology. It is common knowledge that a change of name does not change the content of a subject. Giving pharmacy the name "pharmacology" did not change matters, and, except for a brief period in which it was thought something new was being done in studying the "action of drugs," the same dissatisfaction has followed pharmacology as that which followed pharmacy and "materia medica" in our schools of medicine, whereas no dissatisfaction has ever been found with pharmacy as such.

I suggest a new medical discipline and, consequently, a new name. I have coined a word for it, "biotrepy," or more correctly, "chemobiotrepy," from *bios*, life, and *trepo*, to change. Almost any name would do, however, provided it has a biological rather than a chemical connotation.

It is simple enough to outline a department of biotrepy on paper, but quite a different matter to put it into operation. This could be done with a proper plan together with sufficient financial support, but such cannot be expected without proof of the value of the plan.

Pharmacology was started by Bucheim in his own house with his own money and later was taken over by the University of Dorpat. Growth was very rapid as Schmiedeberg, Bucheim's pupil, was given a great institute at Strassburg from which the heads of nearly fifty pharmacological departments came. For a time this supposedly new field created great interest, which, however, gradually subsided. An analysis of what was done about pharmacology during the period of medical expansion in the twenties will substantiate this view, as will the opinion voiced at that time by Dr. C. W. Edmunds, then President of the Society for Pharmacology and Experimental Therapeutics. To the pharmacologist, the attitude of the medical profession towards "drugs" would have been exasperating if it had not been so naïve. The surgeon could not have operated without "drugs" (general and local anesthetics) and, except for what nature was willing to contribute towards a cure, the medical man relieved his patients by means of drugs only—morphine, cathartics, cardiac and vasomotor drugs, central nervous depressants, antisyphilitics, antimalarials, anthelmintics, and a host of other substances. These were so commonly used that they were forgotten. Now we have the sulfonamides and penicillin. It is difficult to imagine another lapse of interest in drugs, but when one can disregard those mentioned above, he is capable of anything, and once more it may become the fashion to decry therapy and specialize on diagnosis and the autopsy. Those who have spent their lives studying the fascinating reactions of the organism to chemical substances are apt to blame medical administration for lack of support, but I am not one of them. Pharmacology was given a good start with ample support but failed. Biochemistry, founded at more or less the same time, succeeded. Administrators, perhaps with great perspicuity, apparently felt something was wrong with pharmacology and did not wish to commit university funds to such departments. Although unwilling to drop this subject entirely, they were unable to decide what to do about it as pharmacology seemed different from other branches of medicine, and so it was. Biotrepy might solve the problem. It would at least be a true medical discipline, which pharmacology is not.

That we want drugs needs no further comment. Let us consider the purely practical matter of how we are to get them. True it is that the chemist can make drugs perhaps better than anyone else, but he has taught many scientists the secrets of his profession, and more than one biotrepist will be found who can put drugs together as well as many chemists. However, all will agree that the synthesis of chemical substances is a function of the chemist. But if the chemist were to take over this task, what would he make? He already has a million potential drugs on his shelves. Our best chemists are not all biologically minded. In speaking of the great need of a good substitute for quinine in malaria, one of our best-known chemists very emphatically pointed out that this was a simple matter because, as he put it, the malarial organism "is such a damned little bit of a bug." The decision on what types of substances are needed for the cure of disease or for the influencing of a physiological or pathological function is the work of a specially trained biologist, one who knows the organism and disease, and one who also has a working knowledge of the chemistry of the substances with which he has to deal.

If we wish golden eggs, we must have a special breed of goose to lay them, although there are and will be exceptions. An old woman gave us digitalis. Although the biotrepist must be a chemist, he must be much more. He must be trained in the biological sciences and have a knowledge of the reaction of the organism to disease. This does not mean that he must be a skilled clinician. It is not enough to take a chemist, a biochemist, a physiologist, or a medical graduate and tag him as a biotrepist, but he must be put through a long training. We have turned out a few such men, well grounded in the fundamentals of mathematics, physics, chemistry and in the medical sciences, as well as biotrepy. It can be done, with a plan, as clinicians can be trained, but it takes some ten years or more. For this we need money, which is almost impossible to obtain. We have been most fortunate in having had the co-operation of a broad-minded philanthropist in this, but thus far I have been unable to obtain the aid of any foundation in training men, although they have been willing to support research. The training of men—students, assistants, as well as the heads of departments—and the imbuing of these men with the spirit of investigation is the true function of a university; mass production is not.

The training of men is no simple matter. In the past one sought out the great masters and absorbed from them not only information but knowledge and wisdom. At present the mass of facts and techniques is so enormous that one is apt to get lost in attempting to acquire them and to overlook that which makes men great. Investigations are no longer simple. More and more factors need analysis; the investigator becomes impatient and wishes assistants, and they in turn wish technicians. All the members of the resulting large group may not be fundamentally interested in the general field of investigation. With such a group, the investigator is no longer free to change his plans, especially as from this group strings run to financial sources, or, to be exact, to the minds of men who with the best of intentions may pull the wrong string and spoil the show. It is axiomatic to say that in a university academic freedom is desired above all else, and for this an adequate endowment is requisite; but let us consider the practical problems of departments of biotrepy for which budgets from endowment are inadequate, while investigative work of similar nature is being carried out by industrial laboratories under ideal conditions.

There are several methods of operating such a department: First, stay within the departmental budget, regardless of its size, and accept no aid from outside sources. This imposes severe restrictions on members of the staff. Second, accept grants to aid in carrying out work initiated by members of the staff. Third, accept grants to undertake problems suggested by philanthropists or their representatives. Fourth, undertake odd jobs for financial return in order to fill the department, to obtain money for assistants, or to round out the chairman's own salary.

Let us examine the results of these differ-

ent plans. All of them may allow productive research on a scale approximately proportional to the amount of money received. Universities have been operating for the last generation on the plan of "keeping up with the Joneses." Expansion seems to have been the main objective. However, in biotrepy we are beaten at the start in such a race. Industrial and governmental pharmacological laboratories have set standards in size which universities can never reach. On first consideration it would seem that as long as we are beaten, we might as well drop out; and we should if only mass of production is concerned, but quantity of research is not the primary objective of a university. The function of the university is a special one—that of training men, a function which industry cannot take over without in turn forming universities of its own. By co-operation the university and industry can function more economically than by competition. If industry will support the training of men in universities, it will produce a continuous crop of goslings and insure the supply of golden eggs. This is a much sounder and more economical plan than to support competitors or to hand out piecework because it can be done more cheaply in university laboratories, and in so doing upset the proper functioning of university departments. If foundations and philanthropists, as well as the public, can be made to see this, the university will become free once more to carry on the main function for which it exists. The training of men, however, does not consist alone in teaching them known facts, but in their learning how to explore the unknown, which involves the complex, indefinable, and unlimited field of research. Dr. Sigerist has pointed out in a most enlightening article, "The University's Dilemma," that the heads of medical departments are becoming so involved in administration that their productivity is being reduced and if steps are not taken to avoid this the better men will go elsewhere in order to carry on their work. It is obvious that the plan of "keeping up with the Joneses" is not a good one as far as universities are concerned.

The solution of this dilemma is to increase the endowment of university departments to a point where they will become independent. This can be done by educating the public to realize the purpose of universities and, by definite plans on the part of the university, to see that endowment is increased. The latter can be accomplished in the same way that any business concern increases its capital; namely, by not spending all of its income but setting aside a portion of it for capital. It could also be done by requiring that a portion of all grants received be added to the endowment of particular departments. By fixing minimum departmental budgets, and spending a fixed percentage of income only, endowment could be substantially increased over a period of years, and in a university time must be considered infinite. Incidentally, if departmental budgets were made cumulative, it would allow much more economical spending of funds. In order to foster academic freedom in a department, I would suggest, before all else, financial stability; next, the best leader obtainable in the field—not the best administrator, but one interested in the fundamentals. I do not put the man before the money because a good man without sufficient financial support might become a loss to science. Give such a man a respectable salary as suits a respectable man; if we are to breed scientists, guarantee him a minimum salary, a minimum budget, a life insurance and a retiring annuity, and he will be free to devote his energies to his work. Without this, the university is expecting too much of him. With such a plan, a professor, if he wishes, can accept temporary grants to further his own work, but he will feel no urge to expand his department by accepting odd jobs. If he is asked to undertake fundamental research in other fields, he will be free to accept or to refuse. He could collect a group for such work if he desired and delegate responsibility for it to some member of his staff without increasing his own administrative duties, and in so doing he could give his associates valuable experience.

If those wishing to aid mankind by advancing knowledge would put a portion of the responsibility of spending accumulated funds on those who are experts in their fields of science, the former would be relieved of

much of their responsibility and in the long run might, in so doing, accomplish more. It is said by some that the much maligned goose is after all a wise old bird.

Looking into the future we can see the cure of bacterial and parasitic infections with "drugs" and the probability of a chemical understanding of immunity. We can picture also the enormous changes which will come about from nutritional studies when foods, like "drugs," are changing from crude animal and vegetable preparations to pure chemical substances. But have we thought of the complexities of life when enough biotrepy is known? Some day we shall realize that we ourselves are, after all, what we know ourselves to be, a mere agglomeration of molecules. With an understanding of the responses of this complex mass to chemical substances, we can not only become fat or thin, but short or tall, and possibly male or female. When even now by the administration of chemical substances a male can be made to produce milk and nurse young, what limit can we set to changes in physical make-up? Thus far, our pleasant drugs, such as alcohol and morphine, are detrimental to our well-being, but similar substances will be found which are not. We know that mental characteristics can be changed by chemical substances. Life will not be simple. We have not yet reached the end of our rope; perhaps it would be better if we had. Imagine getting up in the morning with the shelves of our medicine cabinets filled with substances which could transform us to fit or misfit the day's work. A little of this and some of that would seem to be the best combination, but then one would discover that he had omitted his "X" and in taking this without due thought had upset the balance between his "Y" and "Z." Jimson's one-a-day pill will not solve such problems. We will have to be "tuned" until everything is in perfect harmony, and only the expert can realize what this means.

The days of synthetic man are here, and here to stay. It would seem time for the medical profession to take steps to handle matters of such importance. A beginning might be made through the organization of departments of biotrepy.

I suggest biotrepy not as something new but as a change in point of view. Biotrepy has always been with us; it is what those in departments of pharmacology have been doing. As soon as it is realized that the study of "drugs" in themselves has no place in our schools of medicine, but that this is a function of the chemist and pharmacist, the first step will have been taken in the right direction. If this can be followed by the organization of departments for the study of the reactions of the organism to chemical substances, we shall be on our way, and if foundations, industry, and the public can be made to realize that it is from well-bred geese that their golden eggs are to come, the way will be clear for uninterrupted progress.

DO YOU KNOW SOMEONE WHO STUTTERS?

By JAMES F. BENDER

If the totals of the deaf, the blind, and the insane are added, the sum is considerably smaller than that of the number of men, women, and children who suffer from stuttering. Baffling in its manifestations, stuttering is called a sex-factor disorder. For example, statistics on sex-factor disorders tell us that there are approximately three times more women than men afflicted with gall stones; *Daltonism* or color blindness is veritably non-existent among the female sex; likewise, hemophilia, or bleeding sickness, is a so-called male disease because only boys and men are afflicted with it. There is approximately nine times more stuttering among men than women.

Once the reason for this disparity is understood, the problem of stuttering will doubtless be solved. But to date we have only speculations about the phenomenon. Some authorities maintain that women do not stutter as much as men because they have a smaller obscene vocabulary. Stuttering, according to this theory, is caused by a subconscious fear of saying naughty words. Others hold that the difference is due to characteristic breathing habits: females favor chest breathing and males diaphragmatic breathing. The most plausible explanation lies in the theory that females experience a more rapid and stable development than males of the brain centers that are believed to control speech. At least we know that girls speak earlier than boys, have larger vocabularies, and fewer speech defects. In other words, the female sex of our species is more gifted linguistically.

Although known to the Egyptian, Greek, and Roman civilizations, each of which prescribed "cures" for it, stuttering still remains a little-understood disorder. There are fifteen or more contemporary theories as to what causes it and many more corrective techniques. As late as the nineteenth century it was believed that stuttering symptoms could be relieved by surgery. In France alone it is said that more than two hundred stutterers were operated on surgically during one year. Wedge-shaped portions were cut from the back of the tongue and various lingual muscles were severed. The tongue was also pierced with needles or cauterized. Sometimes wooden wedges were placed between the teeth. Smoking was often recommended as a sedative to the vocal cords, which were believed to be the main seat of the difficulty. Much earlier, Francis Bacon maintained that the stutterer's fundamental derangement was caused by a cold tongue which needed to be warmed throughout the speaking day by imbibing good, hefty wine. These, and many other, rather bizarre remedies were advocated because stuttering was looked upon as an organic disease. Today that point of view is not widely held.

Whatever the cause or causes, the effects of stuttering are extremely painful psychologically. Here are a few excerpts from autobiographies of stutterers.

> As a stutterer, I experienced a rather consistent bodily and mental state. The defect does not exist merely as an obvious inability to express myself adequately in speech; it involves a generally complicated bodily tenseness as well, and mental uneasiness, a real fear which is apparent as a rule in my halting, shrinking manner of expressing myself, my thoughts, my emotions. I tend to hold myself in because I am afraid I shall stutter.

> Although I believe I was as physically attractive as most of the girls I went with, I never had the invitations that they did to go to dances and other affairs with fellows. I always had a suspicion that they made fun of my stuttering behind my back. Consequently, I never married. No one ever proposed to me.

> I was terribly shy around them [girls] when not in the classroom. However, I do not think I would have been if I had not stuttered. When I saw other boys talking to some of the girls I liked, I felt envious, and even hated myself because I could not talk to them too.

> My only enjoyment was to work alone in the fields and dream of what a great success I was going to be. My success pictures always had the foundation of perfect speech. I disliked working with anyone. That called for conversation and would not let me dream.

> Soon I shall be fifty years old, and while I have much to be thankful for, especially in the way of a

good wife and two fine youngsters, I have been a vocational failure because of my stutter. As the years have rolled along I have seen many men, without as much ability as I have demonstrated, supersede me in rank and salary. Without exception they were competent speakers, and I was a tortured one. Why isn't something done for the stuttering child before he gets too old?

These confessions reflect only a small portion of the characteristic torture that stuttering ordinarily entails. Multiply such experiences by the total number of stutterers in the United States (a conservative estimate being 1,350,000 men, women, and children who stutter), then add the relatives and associates of the stutterers and the results indicate that a tremendous number of people are directly interested in this ancient and as yet unsolved problem of speech and its blighting effect upon the personality.

Within very recent years this interest has been crystallized in research into the problem and the establishment of speech clinics, especially in our leading colleges and universities. As the result of laboratory experiments and surveys, we now know that there is a marked tendency for the onset of stuttering to fall into three periods of life: when speech develops, which is normally around two years of age; between five and seven years of age; and during adolescence. Stuttering usually begins during the first decade of life. Stuttering symptoms do not ordinarily make their primary appearance after a person has matured physically, although they may be intermittent; that is, the symptoms may disappear more or less only to recur at some later time. Even the most confirmed stutterers experience alternate periods of severity and mildness of the disorder. These cycles may vary greatly in duration. Another interesting fact is that more children than adults stutter. This accounts for the widespread and erroneous belief that the trouble is usually "outgrown." Some stutterers reveal their speech disorder only in reading aloud; others, just in speaking; still others, in both activities. For example, certain famous actors and preachers have stuttered consistently in conversation but not in platform speaking. Stutterers can sing without blocking on words, ordinarily they can read successfully in unison with others, and they invariably report that they can talk to themselves when alone without any difficulty. Many of them talk fluently when addressing a much younger or inferior person. One research worker has reported that stutterers can talk with complete fluency while crawling on their hands and knees, even when others are present.

If one were to select one hundred stutterers at random and match them with nonstutterers in regard to age, intelligence, social background, and other such factors, and then trace the speech characteristics of the forebears of both groups, one would probably find six times as many stutterers in the ancestors of the stuttering group as in those of the nonstutterers. In families in which twins tend to recur one may expect to find about five times as many stutterers as the generally anticipated number. Such findings point to heredity as the chief predisposing cause of stuttering.

Why do more children stutter than adults? Once again we can only offer plausible explanations. One research worker has found that stuttering speech in young children learning to talk is more usual than not and that more than 40 per cent of all young children whose early speech is marked by stuttering symptoms "outgrew" them. Perhaps the theory of primary and secondary stuttering is helpful at this point. Primary stuttering is identified by the characteristic gasping breathing, blocks and repetitions on sounds and syllables, tensions and nervousness, and twitching. Psychologically, primary stuttering is marked by unawareness on the part of the afflicted child of the social discomforts that his speech disability entails. Secondary stuttering, the reactions of the stutterer to his speech handicap, is rarely recognized as such until the child is old enough to realize that his mutilated speech results in feelings of unpleasantness—of inferiority and frustration—in social situations. When the child leaves the protection and the sympathy of the home to go to school, the symptoms of secondary stuttering are likely to become evident. If parents nag or show too much concern about the primary stuttering, they may actually encourage the secondary phase, which is generally more difficult to correct. Authorities recommend that the stuttering child be referred to an expert as early as

possible because secondary stuttering, if allowed to develop, fosters personality problems which are likely to grow in complexity with advancing age.

Much has been written about the forced change of left-handedness as a cause of stuttering. The theory is based on the knowledge that the left side of the brain controls the movements of the right side of the body, and, conversely, the right side of the brain controls the left side of the body. It is also based on the hypothesis that the side of the brain that controls the preferential hand, especially in writing, also is the dominant factor in controlling the co-ordinated muscular movements which produce fluent speech. Hence, if handedness is changed by force, stuttering is said to result frequently. Results of surveys do not bear out the contention that all, or most, stuttering is caused by forced change of handedness. In one of the studies that involved 89,000 St. Louis school children, "the vast majority of our left-handed pupils who have been taught to write with the right hand had not developed any speech defects." Moreover, "81.4 per cent of the children for whom definite data were supplied began to stutter before they were given any instruction in writing in the schools." Nevertheless, most psychologists and educators today do not advise the forced change of handedness. "Let nature take its course in this respect" is their advice.

The stutterer frequently gives the impression to many people of being slow of comprehension or even below normal in intelligence—probably because fluent speech is rated so highly in everyday life as an index of intelligence. As a group, however, stutterers are at least normal in intelligence, and there is some evidence to indicate that they are above-average in this respect. For instance, a study of the speech characteristics of a large group of feeble-minded children and adults revealed that almost all kinds of speech disorders were distributed among them *except stuttering.* Again, stuttering is twice as prevalent among students of colleges and universities as among the general population. Moreover, Havelock Ellis reports "the abnormal prevalence of stuttering among British persons of ability." These pieces of evidence, together with the results of intelligence tests of stutterers, indicate that stuttering is not associated with feeble-mindedness; rather, stutterers tend as a group to be gifted mentally.

Despite their intelligence, stutterers need guidance in the solution of their speech and personality problems. It is difficult for them to attain an objective view of their disorder and themselves. If the stuttering has been neglected in their childhood, there is still hope for speech improvement, because stuttering symptoms can be brought under control and in many instances a complete correction is possible. While there is no panacea or magic formula for the correction of stuttering, there are many helpful techniques available for its alleviation. The age and personality of the stutterer determine in large part the corrective approach. But the stutterer needs to beware of the individual or organization that guarantees cure, because there are too many unknown factors in each case of stuttering to warrant such a rash promise.

As an example of one approach to the alleviation of stuttering, the case of Mary, three years of age, is cited. She was an only child who began to stutter when her mother was taken to the hospital. Prior to that time the little girl had been carefully protected from outside contacts and was not permitted to play with other children. During the mother's illness, Mary lived with an aunt, an uncle, and three cousins, four, six, and seven years of age. By the time that Mary returned to her own home she was stuttering quite noticeably. The thought of revisiting her aunt's home was a case of anxiety. She had doubtless experienced a good deal of nostalgia and unhappiness in the strange environment. One of the results was stuttering. The parents were advised to put the child to bed for two days, and a regimen of relaxation and quietude was prescribed. Radio programs were kept to a minimum. Romping and contacts with outsiders were ruled out for the time being. The parents were cautioned not to dramatize the stuttering by suggesting to Mary to speak smoothly or slowly; nor by making sympathetic facial expressions; nor by talking about the stutter. Rather, they were encouraged to ignore it and to speak without excite-

ment and to wait for Mary's words with disarming patience.

Within two weeks Mary was speaking with her former smoothness. After the old speech habits were re-established, Mary's mother was encouraged to widen the youngster's social contacts; but to widen them gradually and to select playmates whose speech was exemplary.

If Mary had been given formalized speech training upon her return home she would probably have become so speech conscious that the stuttering symptoms would have increased in severity or become tenacious. The approach was indirect as it should be in the tender years when primary stuttering takes place, before the child is cognizant of the value put on normal speech by her associates.

An entirely different approach was used to help Mr. X, a business executive of forty years of age. He had stuttered most of his life and had undertaken various kinds of "cures" from time to time. But a promise of a substantial promotion and added responsibility, contingent upon his acquiring control of his speech, gave him a strong incentive to do something about it in a sustained way.

The psychologist explained to him that only he could help himself. That he might well adopt the attitude that his stuttering could not be cured in any miraculous way. But by relearning to speak through conscious management of the speech process, he could at least control the symptoms of stuttering.

Training was then given him each morning, before he reported for work, in *rate-control,* a technique of speaking based upon phonetic analysis designed (1) to awaken aural speech consciousness, (2) to permit accurate diagnosis and isolation of habituated articulatory and vocal defects, (3) to relax the organs of articulation and use them economically, (4) to induce mental ease while speaking or reading orally, (5) to improve vocal quality, (6) to develop conscious control of the mechanical factors of articulation, and (7) to enlarge breath capacity. These principles were applied to the oral reading of sounds, then syllables, and then words, and finally phrases and sentences. Once the technique was mastered in oral reading, the same principles were applied to improvised speaking. He was asked to talk about pictures that were flashed to him. After this step was mastered, he was requested to talk impromptu about a scale of subjects that required ever-increasing attention to the subject matter, always using a rate that allowed him to speak smoothly. The final step was to apply rate-control over the telephone and before a formal audience.

In the case of Mr. X the time required for him to relearn to speak was a year. He visited the psychologist every day, including Sunday, for the first two weeks. Then followed a month of visits on alternate days. He came twice a week for the subsequent five months and once a week thereafter until his speech was completely under control.

Along with the speech re-education went discussions about matters pertaining to his attitudes toward himself and his associates—mental hygiene—for Mr. X, like so many seasoned stutterers, had developed characteristic maladjustments of temperament. As Mr. X's speech improved, his attitude toward himself and a great many things changed for the better. The vicious circle had been broken as soon as he had learned that he could control the speech symptoms of stuttering.

Mr. Y, another business executive of age and background comparable to that of Mr. X, found *voluntary stuttering* a helpful re-educational process. Voluntary stuttering is based on the theory advanced by Dr. Knight Dunlap that "repetition may be employed in dissolving or breaking habits as well as in the formation of habits." The assumption is that stuttering is a collection of undesirable habits that can be eliminated by voluntarily repeating them. Psychologists and speech clinicians who use the technique of voluntary stuttering usually have the stutterer repeat the first sound in each word distinctly and clearly several times, varying the number of repetitions at the beginning of words to avoid establishing a set speech pattern. Whenever a stutterer has a speech spasm while using voluntary stuttering, he is requested to repeat the word until he can say it without difficulty. In the case of polysyllabic words, voluntary stuttering may be practiced on each syllable, each initial

syllable being assigned varying sound combinations; thus, for example, s-s-s-stutter or st-st-st-st-stutter. When the mature stutterer has tics and other nervous mannerisms, he is taught to control them by reproducing them voluntarily before a full-length mirror.

Both rate-control and voluntary stuttering are only two of a large number of re-educational techniques. They are mentioned here to illustrate the old adage, "What's one man's meat is another man's poison." Mr. X found relief in the former and not the latter; and Mr. Y's experience was the exact opposite. That is why the psychologist who handles cases of secondary stuttering needs to know many approaches and to be able to select the most helpful for each individual case. Sometimes he employs a combination of techniques. For example, both Mr. X and Mr. Y were given daily progressive relaxation exercises along with their respective speech re-education techniques. Like most other therapeutic approaches involving human contacts, speech correction is an art as well as a science. The important consideration is that stutterers cannot be put into a Procrustean bed. Each case must be approached to meet its peculiar needs.

Perhaps the most significant single item in the correction of stuttering is the rapport established between the stutterer and his correctionist. The value of rapport, the reciprocal feeling of friendliness and confidence, cannot be stressed too heavily. Once rapport is established the stutter can be attacked by one or more of a variety of techniques known to the specialist. Fundamentally it is because of rapport that so many techniques prove successful. Of equal importance to the stutterer is his need to accept his disorder of speech as part of his fate. He must not feel too sorry for himself, but meet and know the large number of people of accomplishment in all walks of life who have been stutterers. It is the nature of all of us to be handicapped in some respects: stuttering, like chronic indigestion or procrastination or shyness, can often be corrected completely or diminished in severity or compensated—if only the stutterer will give himself the opportunity, and progressive communities will make that opportunity possible.

TO GENE

When I inquire of organismal forms
Where lies the structure that declares them one
Amid diversity, which like the sun
Uniting orbits, limits countless norms
In orthogenic line or spreading tree,
Providing adaptations for each load
In evolutive or regressive mode
As earth's climatic cycles shall decree.

I come upon a molecule, immense
Within the microcosm, limitless
In numbered combinations, hardly seen,
Yet known by chromosomic loci in extense,
A protean form in polymeric dress
A fascinating neatly coiling gene.

—John G. Sinclair

THE PROBLEM OF ORGANIC FORM

I. BUILDING THROUGH FUNCTIONING

By S. J. HOLMES

We commonly look upon embryonic development as a building process in which organs begin to function only after they are formed. It may seem absurd to say that the stomach functions before it acts upon food, and so it would be if we interpreted the term function in the way it is commonly employed. But the stomach does much more than digest food. Like other organs, it assimilates, respires, excretes, produces hormones, and responds to stimuli in many ways. The functioning of all organs involves morphological changes which may be very inconspicuous or at times quite extensive. That structures are in part formed, as well as maintained, through the effects of their activity has long been known. To what extent can we regard such formative effects as explaining the phenomena of embryonic development and regeneration?

The important role of functioning as a building process was especially emphasized by Wilhelm Roux, one of the great pioneers in the field of developmental mechanics. He divided development into two chief stages, the first of which is the period of self-differentiation, in which parts are formed "without requiring therefor the exercise of function." "The second period is the period of formation through functioning," which leads to a further elaboration of structures previously laid down and effects the harmonious interadjustment of all the parts of the organism.

The events of the earlier period in which the organ systems are blocked out and started on their careers of differentiation were interpreted mainly as expressions of heredity. Roux's experiments on the early development of the frog's egg convinced him that the cells differentiate at first as independent units. Whatever harmony there might be in their developmental processes was conceived to be a sort of pre-established one; but, obviously, nicely co-ordinated differentiations could not go on indefinitely, or even very long, in independent parts. Roux therefore concluded that as the embryo becomes more complex the functional interaction of its parts comes to play a role of increasing importance.

Roux's exposition illustrates the common conception of the distinction between building and functioning. He was willing to concede, however, that although an early embryo is a mosaic of independently developing parts, each self-determining element may develop through the interaction and mutual determination of its smaller components. Periods of irreversibility step in at various stages of ontogeny, first for the larger areas or organs, such as the neural tube, and then for smaller parts of each, although leaving the final product with sufficient plasticity to provide for minor structural modifications. Although a proponent of the so-called mosaic theory of development, Roux was fundamentally very much of an epigenesist.

The names of Roux and Weismann are frequently coupled in referring to the so-called Roux-Weismann theory of development. Both of these leaders of biological thought essayed the formidable task of developing a mechanistic interpretation of life, although they wrought out their ideas in different but overlapping fields. Weismann was concerned chiefly with problems of heredity, variation, and evolution, but he later incorporated a theory of embryonic development and regeneration as a part of his general system. Roux endeavored to throw light upon the causal mechanisms of development and direct adaptation. Both were thoroughgoing selectionists and looked upon natural selection as the great explanatory principle by which the apparently teleological features of the organic world can be explained in terms of mechanism; and both devised extensions of the selection principle (Roux's struggle of the parts, and Weismann's germinal selection) to make it cover cases for which the original Darwinian doctrine was

deemed inapplicable. Both postulated a considerable degree of preformation in the egg as to diversity of content and as to the arrangement of parts, and both at first appealed to qualitative nuclear division as a means of securing the proper distribution of formative germinal factors. Roux was wise enough to abandon this latter doctrine, but Weismann was led to elaborate it further. In Weismann's conception, development is primarily a sorting process, and to explain why the right determinants can be located in the right places at the right times he postulated an "organization" of the germ plasm such that the developmental factors would be properly placed through the normal process of qualitative nuclear division.

Researches in experimental embryology, however, dealt telling blows against Weismann's theory of development, and the superstructure crumbled and fell. The early experiments which seemed to favor the mosaic theory were soon followed by others which showed its untenability as a general doctrine. Differences in the behavior of mosaic eggs and so-called regulative eggs are now readily interpretable from a common standpoint. Due more to the geneticists than the embryologists, experimental or other, the old problem of preformation has to a large extent been solved, at least in principle. The geneticist can point to a map of the chromosomes and say, "Here, gentlemen, is the preformed basis of development. We have not, of course, discovered all the genes, and although we cannot tell just what genes are, we can tell very precisely where they are. Nevertheless, the general outline of the picture of the genetic factors controlling heredity and development is fairly clear."

As a result of many experiments on the eggs of many animals, it is now established that the prospective fate of the various parts of an egg is largely determined in an epigenetic manner. Even the most mosaic egg closely approaches, if it does not actually become, an equipotential system if we take it at a sufficiently early period. All eggs have a certain amount of cytoplasmic organization that stands in various degrees of constancy to the location of future organs. But this organization is at first labile and becomes fixed at very different times in different groups.

As a consequence of numerous researches on the influence of organizers and other factors, biologists have become more and more prone to look upon embryonic development as a series of responses to stimuli. Response to stimuli is, of course, a very broad and general category. Real progress toward understanding development is made only when the nature, location, and mode of action of the stimuli are ferreted out and when we learn how responses are co-ordinated in such a way as to produce regulatory results. The older theories of epigenesis which attributed development mainly to the interaction of parts contained no adequate explanation of the regulatory adjustments which are essential to normal development. The same statement applies even more strictly to the theories of preformation. In most theories of development regulation is regarded as due to a sort of collateral agency, doing nothing so long as everything goes right, but ever ready to patch things up when they go wrong. It may be compared to a repair man working along with a builder who slavishly follows a plan outlined in the structure of the germ plasm. A small change in the foundation may cause the builder to deviate from the proper course of construction, which would make a sad mess of his undertaking did not the repair man step in and undo a lot of his work and start it off on a new line. The builder can follow a plan laid out for him, but he lacks the aptitude for making adjustments. These must be left to his much more resourceful companion, who often exhibits considerable ingenuity in employing new methods of achieving his ends. At times the structure may be half destroyed, or it may be remodeled on a new orientation and partly rebuilt. Then the repair man has to take over most of the work and boss the entire job.

Some such conception of the relation between formation and regulation is common. One finds it quite clearly revealed in the writings of Weismann. It is given frequent expression by Roux, who regards self-differentiation of early embryonic cells as typical, but when abnormal relations occur as in the separation of blastomeres or the fusion

of eggs or blastulae to form normal giant embryos, "the whole formation stands over the parts and directs their development," i.e., the regulative power of the whole takes command and overrules the autonomy of the components of the mosaic and makes them conform. Most epigenesists who extended the period of interaction over the entire history of the embryo had no clear explanation of why interaction leads to a norm instead of disorganization. Roux tried to remedy this common defect of theories of development by elaborating his doctrine of the struggle of the parts of the organism. He attempted to apply this principle to explain direct adaptation through overcompensation, functional hypertrophy, and other processes which he showed were involved in the functional period in development. But in his employment of the idea of struggle, as I hope to show in another article, he lost sight of an important consideration, omission of which seriously impaired the value of his theory.

The general failure of mechanists to devise a satisfactory theory of regulation has given much comfort to the vitalists and other opponents of mechanistic theories. The problem of explaining how behavior that seemingly makes for the realization of ends can be accounted for in terms of causally determined activities presents a perpetual challenge to the mechanist, but I think it can truly be said that he is being brought nearer his goal through the significant results of research in a number of fields. Among these we may mention (1) the work of the experimental embryologists; (2) the researches of the geneticists who attempt to ascertain the precise ways in which genes produce their effects; (3) researches by means of X-rays and other methods upon the molecular structure of proteins, the organization of crystalline formations, and the structural patterns assumed by colloids—researches that have opened up fruitful fields in which discoveries of importance for the basic problems of the organization of the cell may be expected at any time; (4) studies on the functions of enzymes, their interactions, and their relations to colloidal structure; and (5) the discoveries of the physiologists, who are revealing the mechanisms by which functional correlations are effected between various organs of the body. Much recent research in physiology has been devoted to the analysis of the interadjustments which lead automatically to functional balance, or what Cannon has called "homeostasis." These have a very pertinent relation to problems of morphogenesis simply because they deal with the mechanisms of regulation. Our bodies are mechanisms so constituted that they respond to stimuli by checking excesses and speeding up deficiencies in the performance of their several functions. We now know much concerning what these stimuli are, where they arise, and the effects they produce on particular organs. And insofar as we can give a causal explanation of their action, we are contributing also toward giving a causal explanation of change of organic form.

Analyses of these interadjustments have shown that they are effected by a number of quite different mechanisms. Hormones, vitamins, mechanical stresses and strains, nerve impulses, products of excretion, and even such simple substances as carbon dioxide are instrumental factors in the processes of adjustment. A highly significant role in homeostatic regulation is played by the bodily fluids, or *milieu interne,* which is much more exacting in requiring proper bodily responses than are the external surroundings of the organism as a whole. Largely a product of the body, it is, except for a few free cells, nonliving. And yet one might almost call it half alive. It has certain aptitudes for self-regulation and makes responses to living cells around it. If it receives acid, it draws upon its alkali reserves to help maintain its normal pH. If it receives OH ions, it proceeds to neutralize them. But these reactions in maintaining an approximate status quo are powerfully reinforced by the living cells which react to its slight chemical changes in ways that tend to keep its composition constant. Long ago the great physiologist Claude Bernard stated that "all the vital mechanisms, however varied they may be, have only one object, that of preserving constant the conditions of life in the internal environment," a statement which so strongly impressed another physiologist, J. S. Haldane, that he declared: "No more preg-

nant sentence was ever formed by a physiologist."

Except to a limited extent confined to highly developed types, organisms have to take their external environment as they find it, but their *milieu interne* they largely make for themselves. From the simplest of beginnings both in phylogeny and in ontogeny, this *milieu interne* has taken on more and more numerous and varied functions as life processes have become more complex. Its functions are intermediate and instrumental as steps in effecting interadjustments. Its constancy must be maintained if it is to serve in so many ways as a means of integrating the physiological and morphogenetic activities of the organism.

The various regulatory processes whose action Cannon has described in his interesting volume, *The Wisdom of the Body,* cannot be divorced from a certain amount of structural change which may be morphogenic in varying degrees. Familiar illustrations are afforded by the formation of callouses, the hypertrophy of heart muscle in valvular deficiency, and the response of the uterine wall to estrogenic hormones. Cell growth and cell multiplication are integral parts of many of these functional adaptations, but between changes small or great studied by the physiologist and the apparently purely constructive operations falling within the province of the embryologist there are many gradations. As Roux has shown, functional hypertrophy plays an important role not only in ordinary functional adjustments, but in effecting the development of organs in the so-called functional period of development. These hypertrophies are often traceable to reactions to specific stimuli. The increased development of mammary glands in preparation for lactation is effected through the influence of hormones. Under proper endocrine control even the rudimentary mammary glands of the male rat may develop to full functional efficiency. More extensive building initiated by hormonal influences occurs when the removal of the left ovary of a fowl is followed by a growth of the minute right gonad; and where castration in the male toad is followed by the transformation of Bidder's organ into an ovary and the subsequent conversion of the rudimentary Müllerian ducts into oviducts. In such cases it is reasonable to assume that the stimulating agent first evokes a certain type of metabolism, perhaps merely increasing a kind that is already going on to a mild degree, and as a result enhancing a specific kind of functioning.

We should look upon functional hypertrophy not as a more or less exceptional emergency reaction, but as an all-pervasive process appearing at all stages of ontogeny from the growth of the unfertilized ovum to the final integrative effort to sustain life. I imagine that it is very busy in the passive-looking cells of a frog's blastula. Each of these cells has many developmental potentialities. Recent investigations on the isolation of parts of early amphibian embryos and their combination in various relations have shown that the direction in which the cells differentiate is determined to a remarkable degree by the kind of association in which they occur. Organ-forming proclivities normally manifested are often over-ridden and directed into new channels that harmonize with the immediate neighborhood. At first the metabolism of these cells is presumably much the same throughout, and the differences that soon appear may be at first only differences of degree. Each cell gives out substances that may influence the metabolism of contiguous cells. In this way certain cells act as organizers to their neighbors, which in turn act as organizers to less specialized areas. One region takes the lead and the rest of the organization shapes up around this starting point. We must regard this inert-looking blastula as a complete organism composed of parts with diverse but complementary functions. We know little of its peculiar physiology, which doubtless includes such activities as assimilation, respiration, excretion, diverse metabolic changes in different parts, tendencies toward differential growth and movement, production of different organizer substances, generation of electric currents and radiations with their possible mitogenic or other effects, and much responding to stimuli. The mosaic period of development is a sort of terra incognita in which unanalyzed processes have been vaguely ascribed to heredity because they

could not be attributed to anything else. It seems reasonable to suppose that much of the integration going on at this stage may be due to hormones or to substances having similar functions. The reactions to organizer substances are largely morphogenic, although they may also be a part of physiological regulation. They are manifested early as differential movements through which gastrulation and other formative activities may be effected, but also internal structural changes are set up which result later in histogenesis. The early histological changes are presumably subsidiary to the discharge of functions carried on by the cells of the blastula. Further specializations of structure go hand in hand with the increasing diversification of functional reactions.

As an illustration of the viewpoint here presented let us suppose that an organism is composed of four parts, A, B, C, and D, with specific kinds of functional activity. They stand in homeostatic, or essentially symbiotic, relation such that if A functions beyond a given rate some other part or parts affected will produce some kind of stimulus, perhaps a hormone, which will inhibit the functioning of A. If A functions less rapidly than a given rate, other parts react by producing stimuli that goad A into more vigorous action. Similar relations obtain for B, C, and D. The result is that a certain constancy, or balance of functional performance is automatically maintained. The organism is a self-regulating mechanism because it is so constituted that each part responds to the reactions of its associates by speeding up or slowing down its rate of functioning according to the kind of message it receives. One of the most noteworthy features of recent physiological research is the discovery of more and more cases of the kind of relationship between organs here described. But one may object that functional balancing can be explained only when there is an adaptive mechanism to start with, just as one can explain the regulation of time-keeping in a clock. And as a clock does not build itself, so, it may be claimed, we must look to something besides the organism's own functioning to explain its structural make-up.

But organisms really do build themselves through functional adjustments. The only question is as to how far the process can go. Can we say that the whole process of development is just one grand series of homeostatic efforts? This, I concede, is quite too sweeping and grandiose a generalization to be justified by the facts, since there are certain morphoses not evoked by homeostasis. Nevertheless, the structural developments due to balancing may be sufficiently numerous to become the chief guiding influence of ontogeny. In accordance with this interpretation the adaptations of ontogeny with the regulatory activities operating at every turn, bringing about co-ordinated growth processes, inhibitions, unbuilding and starting along different lines, repair of injuries, and various other integrative processes, both normal and exceptional, are susceptible of essentially the same kind of explanation as the interadjustments of the functions of the adult body. One may conclude, therefore, that formative physiology and functional physiology are one.

The period of self-differentiation is quite as much a functional stage as any other stage of development. It is through functional interaction that the self-determining areas are first blocked out, and it is by the same means that the subordinate regions of each are differentiated into harmoniously organized parts. Early co-ordination is, like the co-ordinations in the behavior of primitive animals, largely effected by a step-by-step process. Parts early organized act in turn as organizers. Each step in morphogenesis may be regarded as a matter primarily of functional adjustment, a part of the general process of homeostasis, or balancing, as much as the various processes subsumed under this name in the adult body. One might conceive of the integration of the first developmental stages of the frog's egg as resulting from hypertrophying one or another of the primary physiological processes of the cell. We know little of the steps by which the physiology of the blastula becomes converted into the physiology of the mature body, but the process must be one of continuous orderly evolution, like the increasing elaboration of embryonic structures.

In the higher animals the step-by-step

method of securing co-ordination is supplemented by the evolution of two important organ systems, the endocrine glands and the nervous system. Increase in size to be effective must be conditioned upon the development of means of readily co-ordinating the activities of remotely situated organs. Although every cell may be assumed to produce hormones or some other substances which diffuse out and affect contiguous parts, the endocrine organs of higher animals elaborate secretions that exercise a much wider influence. Such action is greatly facilitated by the movements of the blood and lymph, and it may result in marked changes in form as well as in function, as is illustrated by the morphogenic effects of the secretions of the thyroid, anterior pituitary, and the sex glands. Equally striking are the morphogenic changes effected by the nerves. The transformation of ordinary epithelial cells into taste buds under the influence of contact with sensory nerve endings and the reversion of these cells to epithelium after the nerve supply is cut are illustrative of the morphogenic potency of nervous influence. The sensory nerve ending is apparently an organizer for the development of taste bud cells. We may say that nerve endings affect the metabolism of these cells in such a way that they respond by manifesting a new potency. This morphogenic influence is probably chemical like that of the endocrine glands. Physiological investigation has shown that nerve cells and their processes really are endocrine glands secreting acetylcholine, adrenalin or some similar substance, and possibly other products. Nervous co-ordination and endocrine co-ordination, therefore, rest on a common basis. The nervous system performs its endocrine functions much more precisely than the other endocrine organs. We might define nerves as chemical applicators analogous to those employed by a rhinologist who applies a chemical to a particular spot of one's nasal membrane. By applying its hormones in sharply restricted areas the nervous system is able to function efficiently in securing nice and delicate co-ordinations required in the life of the higher animal.

The development of long-distance co-ordinators introduces nothing essentially new in addition to the integrating mechanisms of early ontogeny. At all stages we are dealing with the response to chemical substances producing formative as well as physiological reactions of an integrative sort. Some of the substances are hormones in the restricted sense; others may be as simple as carbon dioxide, which is an important factor in regulating respiration and the hydrogen ion concentration of the blood.

The organism is always building to meet present requirements of functional equilibration. Its parts may function later in a quite different way, but that has nothing to do with physiological mechanisms of their production. Homeostasis occurs at every stage of ontogeny, and whether the reactions are predominantly morphogenic or physiological is incidental upon the conditions prevailing at any given period of development.

The whole trend of research in experimental embryology is to bring embryology and physiology into more intimate relationships. But whether or not formative actions attributed to organizers are designated as functioning is of little importance so long as we recognize that such actions are subject to regulatory control at all periods of development through the mechanisms of homeostasis.

Any analysis of developmental processes soon brings us face to face with the obscure problem of histogenesis. That the way in which a cell differentiates may be a result of its peculiar organic setting is a frequently demonstrated fact and may be determined by the kind of genes which are aroused to their specific enzyme activity through the evocatory influence of co-ordinating parts. Gene expression, as is well known, may be influenced by environmental factors. Whether the genes are autocatalytic enzymes or are the producers of enzymes, we may reasonably assume, as is often done, that they have the capacity for setting up a great variety of chemical changes which have different morphogenic effects. We may suppose also that the reactions which the genes have been attuned to perform through the long action of natural selection are of the kind that make for functional integration and harmonious morphogenic differentiation.

Natural selection has constructed organisms to respond not only to outer stimuli by proper behavior, but also to internal stimuli by appropriate functioning and morphogenic reactions. Life is not only "the continuous adjustment of internal relations to external relations," as it was defined by Spencer, but the continuous adjustment of internal relations to other internal relations. Through the first the organism is preserved; through the second it is not only preserved but built.

Assuming, then, as a very tentative hypothesis, that the course of building the organism has been largely guided by reactions evoked in balancing physiological activities, we must postulate that the latter in turn depend upon physical and chemical processes, some of which are directly morphogenic. We may call these the primary morphoses. The fairly definite pattern assumed by the fibrous structure of some colloids under the influence of external stimuli suggests an origin akin to that appearing in certain crystalline formations. One might by a sufficient stretch of the imagination look upon the structural pattern of a muscle cell or an infusorian as an expression of the way in which the protoplasm forms a gel. The tendency of gels to produce more or less definite patterns under the influence of external stimuli may have much to do in determining the specific types of cell structure appearing in histogenesis. We are here dealing with basic physical and chemical factors of form production which may underlie the physiological processes involved in the co-ordination of organs. But granting that the formation of cell structures may be accounted for in part as a result of processes akin to crystallization and the pattern formation of gels, it would seem absurd to apply the same explanation to the complex organization of a bird or a mammal, especially since the goal attained is not something fixed, but is a moving equilibrium assuming countless forms from the egg cell to the senescent body.

But even the building stones must be fitted for their proper places. Typically a crystal is a fixed form with the same molecular composition throughout. But in an organism the substances which tend to build themselves up into patterns under the influence of their polarities are varied and continually changing. At all stages they are affected directly or indirectly by the differentiating influences of genes. They are affected also by the organizing influence of substances and possibly peculiar forms of energy received from other cells. The pattern into which the proteins of one cell tend to gel may be changed through chemical or other actions set up through the influence of its particular cellular environment. The primary morphoses and more complex physiological reactions play interacting roles in the integration of development and regeneration. The cytoplasm of early embryonic cells has the potency of forming a great variety of structural patterns. The possibilities of variation in protein composition are almost endless. But the patterns built up in one part under the influence of physical and chemical processes may depend on the kind of functioning that goes on in another part. Even these purely physical and chemical pattern building processes are under the guidance of genes, and their activation is subject to a sort of social control by their organic environment.

The main problem in form production is the proper ordering of the many physical and chemical morphoses which the protoplasm of a species is capable of undergoing, and hence an adequate interpretation of organic form must include an explanation of morphogenic processes on the physico-chemical plane combined with an explanation of integration on the physiological level that may exhibit relationships to the phenomena of social life. In isolation these physico-chemical morphoses seem stereotyped enough. But when properly combined in an organism their aggregates become subject to a sort of democratic control and may exhibit an unexpected capacity for self-government.

(*To be continued*)

SCIENCE ON THE MARCH

WHITHER PETROLEUM?

Many of our ancestors of a century ago had not heard of petroleum. Some along the advancing pioneer front had encountered its use by Indians, who obtained it from seepages. Our grandfathers began to hear more about it and to use a derivative in the "coal oil" lamps which were displacing the common tallow candles. One of the most revolutionary sources of power—the internal combustion engine driven by petroleum derivatives—did not have commercial application until Daimler in 1887 successfully produced a motor car. Now, the high stakes in World War II are being gambled over the globe by use of indispensable supplies of petroleum to manufacture rubber, plastics, TNT, and other materials and to power and lubricate almost countless machines on land and sea, in the air, and under the sea.

What an amazing contrast has developed in a half century in the use of petroleum, to the end that this generation has come, unconsciously perhaps, to assume unlimited petroleum as an inalienable birthright!

General opinion credits the discovery of petroleum in this country to the oil well drilled in 1859 by Colonel Drake near Titusville, Pa. This "discovery well' was presumably a wildcat venture. The operation was based on improvements made in drilling tools and technology since the first well was successfully drilled in 1808, in the search for salt water, at the Great Buffalo Lick near Charleston, W. Va.

The Drake well was a historic landmark in the deliberate search for petroleum. Several earlier discoveries of oil had been made, incidentally and often exasperatingly, in drilling wells for salt and later for ground water. It was reported in 1833 by Hildreth, the Ohio Valley geologist, that a well bored for salt in 1814 near Marietta, Ohio, supplied enough petroleum to be marketed for lighting purposes. That well apparently was the first petroleum well in the United States. Between 1814 and 1859, at least ten other wells containing natural gas or petroleum were drilled in Ohio, West Virginia, New York, Kentucky, and Pennsylvania. The gas and oil were accessories, of limited local use, to the desired salt or ground water.

The sensational Spindle Top gusher near Beaumont, Texas, began to flow in January, 1901. Unlike any well drilled previously in the United States, it sent almost continuously a 6-inch stream of oil to a height of 160 feet until it was capped nine days later. The daily flow was conservatively estimated to have been 70,000 barrels. One wonders as to the productive capacity of this well if the diameter had been twice as large. Within three years more than 40,000,000 barrels of crude petroleum had been obtained within a radius of 30 miles from Spindle Top. What a contrast with the total oil production in Texas in 1895 of only 50 barrels! California in the same year was producing more than a million barrels of oil, but the production in Oklahoma was only 37 barrels.

Discoveries during the next several years signalized the development of an epochal industry whose future could scarcely have been fully imagined. The rapid progress in discovering and developing new fields throughout the United States and Canada revolutionized American industrial economy and changed radically the American mode of living. During the last third of a century the numerous indispensable products of petroleum have become commonplace, even in remote hamlets throughout North America. In the relatively short span of World War II, they will become familiar around the globe.

One billion barrels annually of petroleum in the United States was for the first time produced in 1929. It was derived mainly from nineteen states. Texas, California, and Oklahoma yielded more than 824,000,000 barrels. Production declined somewhat during the lean years of the depression but was again more than a billion barrels in 1936. It reached a peak of more than 1.5 billion barrels in 1943. This production was chiefly from twenty states with about half of it from Mid-Continent fields. California and the

Gulf Coast each contributed more than a quarter billion barrels.

Whither petroleum in the near future and in the long-range planning of our national economy? The answer to that pressing problem depends upon the viewpoint and upon the recognition and proper evaluation of many interrelated factors. It is a complex problem to which no universally accepted solution can yet be given.

Speculations of those who are not intimately of the petroleum industry range from deep pessimism to roseate optimism. This is in part a reflection of the attitudes of a multitude of petroleum geologists, engineers, and executives who are not yet in general agreement on the future of petroleum in this nation. As well stated recently by a leader in the industry, "the facts do not warrant a defeatist attitude of mind but they call for a realistic recognition of the true situation."

What are some of the pertinent facts? Some 26 billion barrels of crude oil have been produced in the United States. We produce and consume three-fifths of the annual production of the world. Petroleum constitutes one-third of the annual production value of all of our diverse mineral resources. Proved reserves are slightly more than 20 billion barrels. They are known to be extractable by present methods from fields that have been sufficiently drilled to afford reliable conservative estimates. Texas, California, and Louisiana contain 80 percent of these proved reserves. Known reserves have doubled in the last fifteen years. Similar reserves in foreign countries amount to more than 33 billion barrels.

During May, 1944, the daily demand for domestic crude petroleum reached a new record of 4,563,800 barrels. That amounts to almost 1.7 billion barrels a year. At the present rate of consumption, our proved reserves would hardly last for the fifteen years that is the common conservative estimate of our national supply. Upon return to peacetime pursuits it is questionable whether the annual demand for petroleum would be significantly decreased, at least as compared with prewar use. It is also open to question whether all of the proved reserves could be extracted during the period of their estimated availability. They might require twice as long to be fully recovered. It is also of concern that new production in established fields and discoveries of new fields have been lagging for several years behind the rate of consumption. Hence, the pessimists have grounds for their disbelief in the long-continued functioning of petroleum as a major element in our "Oil Age" economy.

Another side of the picture, however, presents itself to many who have the mental and scientific initiative, faith, and courage to disbelieve that the "Oil Age" has either reached its prime or is approaching senescence. Many possibilities for the increase of our petroleum supply are evident. Early drilling was done at the sites of oil seepages or other oil and gas shows. Then came an epoch of random drilling—wildcatting—which is still legitimately in vogue. During the last three decades especially, the function of geology in exploring for petroleum has become increasingly evident. The principles and processes of geology are receiving, and will receive, more extensive and intensive application than even in recent years. Sedimentary rocks in which oil could occur are being studied in great detail in the field and in the laboratory.

Petroleum engineers have also been aggressive in developing better production and refining methods. Their contributions to the recovery of petroleum will undoubtedly be of increasing value in meeting the demands of the future. Secondary recovery processes have been applied to declining wells and will be used increasingly in the future. Although a producing oil well has been drilled to a depth of 15,004 feet, it is probable that even deeper zones of possible oil-bearing strata will be tested. Geophysical exploration has contributed much in recent years to our knowledge of these deeper rocks, even to depths of 30,000 feet. After the famous Spindle Top field had been in production for twenty-five years, an equal amount was produced from deeper strata. Efficiency in the use of petroleum will be greatly increased by automotive and other engineers.

No doubt the ultimately available supplies of petroleum in the United States will be supplemented by supplies from foreign lands. The proved reserves in those coun-

tries may be only a fraction of the petroleum that can be extracted, as much geologic and geophysical exploration remains to be done.

Long before our petroleum supplies have approached the vanishing point, synthetic liquid fuels will become available. It is estimated that our oil shales could furnish 92 billion barrels. It has been estimated by competent engineers that our coal could supply us with both solid and liquid fuels for 1000 years. Synthetic alcohols no doubt will be developed for some of the present uses of petroleum.—ARTHUR BEVAN.

FAMILIES AND BAD TEETH

IF you are allergic to the dental drill—and dentists' bills—you should have chosen your relatives, especially your immediate ancestors, more carefully. In other words, if you don't like carious molars you can blame gran'ma and gran'pa. This, in substance, is the conclusion of Drs. H. R. Hunt and C. A. Hoppert of the Departments of Zoology and Chemistry, Michigan State College, who made a study of the inheritance of susceptibility and resistance to dental caries in albino rats. The rats were fed on a diet, devised by Hoppert, which permits normal growth, health, and reproductive vigor, but which induces caries in the lower molar teeth. By weight, the diet is 66 per cent coarsely ground polished rice, 30 per cent whole milk powder, 3 per cent alfalfa leaf meal, and 1 per cent NaCl. The diet was instituted at 35 days after birth, and the molars were carefully examined at 14-day intervals. To date 3164 rats have been observed, many as high as 50 times.

The study was started in 1937 when 119 rats were started on the caries-producing diet; of these 116 survived and showed cavities in a time-range of 28–209 days, with an average of 70 days. From these animals, by selection and inbreeding, caries-susceptible and caries-resistant strains have been developed. The close inbreeding reduced heterozygosity by about 19 per cent of the heterozygosity of the preceding generation.

In the caries-susceptible strain the mean for the onset of caries declined from 57 days in the second generation to 22 days in the eleventh generation. In the caries-resistant strain the mean for the second generation was 116 days, and for the eighth generation 195 days, though in the sixth and seventh generations the means were 248 and 245 days, respectively. In the caries-susceptible strain variability was relatively low. In the caries-resistant strain it was uniformly high, and some of the animals go through life without caries.

It seems to have been demonstrated, almost beyond doubt, that inheritance is a very real factor in susceptibility and resistance to caries in rats. But the genetic picture is still hazy; there is no precise information concerning the gene difference between homozygous susceptible and resistant rats; nor is there any detailed knowledge of the modes of action of these genes or gene-combinations. Research into hetero- and homozygosity, into back-crossing, and into crossing the two strains, still remains to be considered. Still, the principle of hereditary transmission seems to have been firmly established.—W. M. KROGMAN.

SOILS TAKE A REST

PLANT growth has been so long accepted by the human race as a matter of course that the continuous functioning of the soil in producing it—if recognized at all—is seldom questioned. Recent concepts of the mechanism of plant nutrition as an exchange between the nutrient ions adsorbed on the surface of the clay particles and the hydrogen or other ions on the plant roots are explaining crop failures and lowered yields in terms of deficiency of available nutritive elements. Such unproductive soils are taking a rest.

The dozen or more chemical elements coming from the soil for plant construction originate in the rock minerals that form the soil. The sand and the silt fractions are rock particles and crystalline minerals not yet decomposed, while the accompanying clay is a seemingly formless product of the rock's chemical change. Clay has little in its molecular structure to contribute to plant nourishment by its own breakdown. But as adsorbers and exchangers of nutrient ions most clays are very effective because of the tremendous surface of their particles. Clay serves as the "jobber" to give its adsorbed nutrients to the plants for hydrogen taken in exchange. It then passes this acidity to

the silt and other minerals to break them down and accept in its place those nutrient elements so obtained from these rock crystals. It is by this mechanism that nutrients are passing from the rock minerals through clay to the plant. Hydrogen as acidity from root growth is passing in the opposite direction. Plants are thus continually exhausting the clay's stock of plant nourishment. It is this exhaustion that produces the phenomenon of resting soils.

Recent plant-soil studies using clay only for plant support showed that a single crop removed the supplies of adsorbed nutrient elements from the clay to an extent ranging from 25 to 85 per cent. Of those elements tested, adsorbed potassium was most rapidly and completely removed. The concentration of acidity or hydrogen on the clay had gone up as the nutrient went down.

These facts point out clearly, then, that after one crop has taken most of the nutrient ions from the clay there could be little for a crop following immediately on the clay. A clay so nearly exhausted then takes a rest from plant production while it restocks itself with nutrient ions from the less active rock particles. It rests from crop production but is active in getting rid of acidity and taking on nutrients by weathering the reserve minerals.

The fall and winter seasons are rest periods of the soil. Low temperatures rule out crop growth but not these beneficial chemical reactions in the soils. Time intervals between crops at seasons other than winter serve similarly. These needs for the soil to take a periodic rest from crop production as indicated by crop failure following immediately after another crop have sometimes been interpreted as injurious or poisonous effects by one crop on another following it too closely. The so-called crop injury has been simply a case of starvation for the soil-borne nutrients. Early plowing in the summer for fall-seeded wheat is a method of hastening recovery from nutrient exhaustion, once explained as moisture accumulation and more recently considered as nitrate accumulation and restocking of the exhausted clay by means of mineral breakdown.

Continued cropping on some experimental plots is demonstrating not only the exhaustion of the clay, but also the exhaustion of the soil's mineral reserves. Where wheat, for example, has been grown annually for 55 years at the Missouri Agricultural Experiment Station, the gradual decline in crop yield for almost 40 years of that time is being followed during the last 15 years by an alternation of crop and noncrop years. This soil is taking a rest each alternate year, demonstrating the fact that not only the clay is exhausted of its nutrient store after a wheat crop in July, but that the mineral reserve has been weathered out so nearly completely that the clay is not sufficiently restocked in October to permit the crop then seeded to go through the winter. Oats as a spring crop, following a winter rest period, are more successful on soil after a preceding summer legume crop of lespedeza than is wheat seeded in October following right behind it. Fallowing at any time is an induced rest period and is an effective agent for a better crop because a better nutrient supply becomes quickly available on the clay and because the water is stored by it.

Intensive cultivation with its depletion of the nutrient stores in our soils is decreasing the grazing season of grasses, is maturing reduced yields of grain crops earlier, and is reducing the yields of seed crops. As we seek to grow more crops by continued cropping and intensive cultivation, the soil takes more rest except as we replenish its nutrient elements by the application of fertilizer. Without such applications the resting clay of the soil restocks itself too slowly.

Our urgent need for increased food production is bringing us to realize that our soils take a rest because we are not giving them sufficient help to save them from exhausting their stock of nutrients required for continuous plant growth.—WM. A. ALBRECHT.

BOOK REVIEWS

SPHEROGRAPHICAL NAVIGATION

Spherographical Navigation. D. Brouwer, F. Keator, and D. A. McMillen. Illustrated. xxiii + 200 pp. $5.00. Feb., 1944. Macmillan.

THIS specialized book of navigation is essentially an instruction manual for solving the problems of navigation on the newly created sphere developed by Drury A. McMillen of Brazil.

The idea of a graphical solution of the astronomical triangle on the surface of a sphere is not new, but this method has, heretofore, lacked the required precision for practical ocean navigation. To overcome the difficulties, the inventor has had constructed a precision-made sphere with the necessary supplementary gadgets for drafting. These consist of (1) the spherical compass, with the scribing point and a movable center point with micrometer adjustments; (2) a graduated great circle, by means of which a great circle arc may be drawn on the sphere; and (3) a spherical protractor which furnishes a means of measuring angles formed by the intersection of any two great circles, the divisions extending from 0° to 180° by half degree steps.

Even if the astonishingly high degree of accuracy for this method as claimed by the authors is not generally obtained in practice, the precision of the spherographical system is sufficient for air navigation, where uncertainties of 15 to 20 miles could make a difference in flying time of not more than 4 or 5 minutes.

The McMillen three-dimensional system has the merit of presenting the true geometry of celestial navigation; and it requires no knowledge of the dead reckoning position of the plane since the circles of altitude can be drawn on the sphere with no other information than the chronometer reading of the time of the sights, the sextant altitudes of the stars, and the information contained in the Air Almanac. As with any other method the position obtained must ultimately be plotted on the pilot's map or chart of the region flown.

The authors cover in this small handbook specific cases and problems of navigation that will be encountered in spherographical solutions. While the authors illustrate the problem of daytime navigation by sun-sights alone, it will be obvious that while waiting for suitable elapses of time between observations of the sun to yield a favorable angle of intersection of two lines of position in azimuth, the accumulated errors incident to carrying forward a line of position during this interval can be considerable, being based on instrument flying alone.

A particularly valuable chapter is that dealing with polar flights, where the spherographical system has the advantage in solving some of the situations encountered in very high latitudes.

The book is in no sense a general treatise on navigation, nor would the authors so claim. It is a small volume of less than 200 pages, well printed, but relatively expensive, as must be the equipment for which the book is specifically written as a manual of instruction.—HARLAN T. STETSON.

RIDDLES IN MATHEMATICS

Riddles in Mathematics. E. P. Northrop. Illustrated. viii + 262 pp. $3.00. 1944. Van Nostrand.

THIS timely book dexterously builds upon the currently increased interest in mathematics and the ever-present relish for puzzles to impart some solid mathematical principles. The author attempts to do this with a minimum of pain and a maximum of attractiveness to the student, and his efforts must be adjudged fairly successful. Most of the book is avowedly for the reader with only elementary preparation in mathematics.

Opening with a definition and examples of paradoxes, the book goes on to a "few simple brain-teasers." These are all of the order of "catch questions," and close attention to wording will be sufficient to solve them. They involve, however, logical or mathematical thinking, and lead the reader on to more serious problems. Succeeding chapters are on paradoxes in arithmetic, in geometry, algebraic fallacies, geometric fallacies; paradoxes of infinity, of probability,

and of logic. The last chapter ("not for the novice") deals with paradoxes in higher mathematics. Appendices function somewhat as do pages of answers in a mathematical textbook for more formal study; they give brief but clear explanations of the fallacies shown in previous pages. A section of notes and references gives many sources and an idea of historical development of the subject.

The chapter on paradoxes in arithmetic is mainly concerned with an effort to give large numbers a real meaning to the reader and to show the magnitude reached by small numbers with large exponents. The "Tower of Hanoi" with its 2^n-1 manipulations is discussed; number theory, including prime numbers and possible systems other than the decimal system, takes some space. Several parlor games are discussed, which are based on familiarity with number systems and algebraic principles.

The chapter on geometrical paradoxes deals with optical illusions, the Fibonacci series and its occurrence in leaf arrangements, extreme-mean ratio, and "logarithmic spirals." The amount of revolution in rollers used to move a slab, properties of curves and cycloids, topology, open and closed surfaces, knots and bordering colors are discussed. Surprising or curious truths bulk large in this section. The later chapter on geometric fallacies deals largely with spurious proofs. They are built up by familiar methods, backed with inaccurate constructions. Tracing out the inconsistencies furnishes good exercise in logic. Use is also made of zero quantities.

The chapter on algebraic fallacies tends to develop familiarity with algebraic manipulations. The fallacies are largely based on cleverly disguised divisions by zero or illogical use of square roots of negative quantities.

"Paradoxes of the infinite" deals with problems of convergent and divergent and oscillating series, and limits of convergent series. Curves, boundaries, and other concepts are related to the idea of infinity. The ideas of one-to-one correspondence and transfinite numbers are developed, and it is brought out that some ordinary numerical standards break down in dealing with infinity.

Some problems in probability are presented, after stating general principles. Then the changes that come in ideas of probability with an infinite number of possible outcomes are discussed. Necessity of clear definition of probabilities is stressed. Logic is discussed briefly; the paradoxes cited seem to border on the trivial after the heavy diet of preceding chapters.

The last chapter starts off with a paradox in higher mathematics which is a dressed-up version of Achilles and the tortoise. A number of fallacious proofs based on misapplications are shown; their study should be valuable in developing facility in operations in trigonometry and calculus.—F. M. WADLEY.

ASIA'S LANDS AND PEOPLES

Asia's Lands and Peoples. George B. Cressey. Illustrated. vii + 608 pp. $6.00. 1944. Whittlesey House, McGraw-Hill.

THIS work is monographic in scope and is a product of some one hundred thousand miles of travel in Asia and of two decades of research on part of the author, who, in addition, also has had active co-operation of a considerable number of leading authorities on the subject, making the survey sufficiently definitive as to be almost encyclopedic in character. It presents a comprehensive, readable analysis of the physical and human problems of Asia, especially China, Japan, the entire Soviet Union, and India. The introductory matter includes discussion of the interests of the United States in the Pacific since the days of clipper ships. Then there follows regional treatment beginning with China and Japan. Subdivisions in treatment of China include such subjects as the Chinese landscape, China's physical environment, farming in China, regions of North China, regions of South China, regions of Outer China, and China in the New World. Subdivisions in treatment of Japan comprise such subjects as Japan's natural foundations, the human response in Japan, regions of Old Japan, regions of Outer Japan, and Japan's world position. In like manner those for the Soviet Union consist of such matters as the Soviet realm, environmental factors in the Soviet Union, mineral resources in the Soviet Union, economic developments in the Soviet Union, regions of Soviet Europe, regions of Soviet's Middle

Asia, and regions of Soviet Siberia. Similar discussion of Southwestern Asia treats in detail of the Southwestern realm, Turkey, Syria and Palestine, Arabia, Iraq, Iran and Afghanistan. Like treatment of India comprises India's physical foundations, India's people and their activities, regions of Northern India, regions of Peninsular India, and India's place in the world. The remainder of the book deals with Southeastern Asia under such subjects as the Southeastern realm, Burma, Thailand, Indo-China, Malaya, Netherlands Indies and the Philippine Islands. There also has been included a valuable selection of suggestive readings on the various countries and subjects, limited to more readily accessible literature, though no attempt has been made to list or evaluate the great mass of material from Asiatic sources or that in European languages other than English. The illustrations have been selected with great care from widely separated sources and comprise an outstanding feature of the book. Equal care and consideration have been given to the maps: in order to convey a proper sense of proportion, most of the maps are reproduced on uniform scales and a single azimuthal equal distance projection, so that they may be fitted together if desired. Separate scales are provided for Asia as a whole, for countries and realms, and for vicinity of cities. It is fitting also that mention here be made of the unusual readability of this book. Even those who merely examine it superficially will notice the condensed, compact arrangement of subject matter, and all will approve of the striking manner in which much of its information is arranged so as best to emphasize a point, or bring out clearer a thought, or otherwise make "good reading," as for example: "The key word in Soviet geography is continentality. Within the Union is room for all of the United States, Alaska, Canada and Mexico. From Leningrad to Vladivostok is as far as from San Francisco to London—nine and a half days by the Trans-Siberian Express." It seems exceedingly fortunate that this book should come off the press at this particular time, in view of the prominence of Asiatic countries just now in World War II. Information contained therein doubtless will enable many of its readers to gain clearer understanding of the physical and human background as well as actual status of that vast drama in various countries, and, to quote the author: "Where controversial issues are involved, these chapters should enable one to bring his prejudices up to date."—J. S. Wade.

ATOMIC NIGHTMARES

Mr Tompkins Explores the Atom. G. Gamow. Illustrated. x + 97 pp. $2.00. 1944. Macmillan.

The public is fortunate in having so competent an authority on the structure of matter explain its mysteries in such a whimsically humorous and delightfully stimulating manner. For the greater part of the book no formal exposition is given. What Professor Gamow has very cleverly done is to construct his book in two parts: the first part consisting of three amazing dream-adventures of Mr Tompkins and his wife, Maud, and the second of the four lectures which inspired these dreams.

In the first of these startling dreams, Maud is taken for a tour among the molecules inside her husband's Scotch and soda. Following this crazy experience Mr Tompkins drops off to sleep during a lecture on electrons, only to dream that he himself is a valency electron in a sodium atom. After experiencing all the varied phenomena that electrons undergo, he (the electron!) is finally annihilated in an encounter with a positron. Mr Tompkins awakens. The next exciting event occurs when Mr Tompkins is knocked unconscious in his father-in-law's nuclear physics laboratory by accidental contact with high tension apparatus. This time he dreams that he meets a "woodcarver" of nuclei through whom Professor Gamow presents a very fine popularization on the composition of the nucleus. Mr Tompkins recovers from his shock and swears off ever having anything to do with physics lectures or laboratories. However, the reader, who by now has been acquainted painlessly with the terminology and elementary facts of atomic structure, has no such wish; on the contrary he is anxious to read the four lectures that follow.

These lectures, entitled "Reality of Atoms," "Inside the Atom," "Holes in Nothing," and "The World Inside the

Nucleus," are models of lucid exposition. The reviewer, a former student of Professor Gamow, can testify that the same clarity and plausibility that characterize his classroom lectures have somehow been imbued in the printed word.

This very entertaining and instructive book will be invaluable in bringing the layman up to date in atomic and nuclear physics, a field of ever-increasing importance and of extremely vital future significance.—JACOB POMERANTZ.

ROBERT BOYLE

The Life and Works of the Honourable Robert Boyle. Louis Trenchard More. xii + 313 pp. $4.50. 1944. Oxford University Press.

ROBERT BOYLE, the "Sceptical Chymist" of the seventeenth century, was one of the great original thinkers of the English heritage. It was his lot, during an age when science was finally breaking away from medievalism, to direct it toward the new empiricism. He became known not so much for his own discoveries in themselves as for the foundations he laid, the philosophical inquiries he set going, and the innovations he made in ideas and methods that others were to pursue. It was an age of great and fearless minds, of whom John Milton, Isaac Newton, and John Locke were probably the greatest. Robert Boyle was of their company.

All this makes Boyle pre-eminently worthy of the excellent biography that Professor More has produced. It is not his science alone, however, that makes Boyle's story so significant, but his consummate humanism. He was a man of his times, when people may have been gullible but they were also inquisitive. He would have been puzzled by the man of science as we know him today, too often preoccupied with some small segment of knowledge and fearful of stepping over the boundaries of his specialty. Boyle was not afraid of getting out of his field, for the whole universe and God and nature were his field, and his inquiring mind recognized no limits. At times it was hard to tell whether he was more theologian or scientist, but to him and his age there was nothing incompatible in being both at the same time. He could write, with equal authority, *Reflections upon the Eating of Oysters, Some Considerations Touching the Style of the Holy Scripture,* or *Spring and Weight of Air.* It was a two-faced age, "half scientific and half magical, half sceptical and half credulous," and if Boyle at times slipped into pure credulity, or held too long to some of the dubious tenets of the alchemy, we must remember that Boyle's age, with respect to the progress of knowledge, must be compared with earlier centuries, not with later ones. The goal of the humanist was to attain as equable a balance as possible between worldliness and otherworldliness, and the degree of such balance achieved by Robert Boyle would have delighted old Erasmus himself. So, while he embraced the mechanistic philosophy, he sought at the same time to reconcile it to his religious orthodoxy and being a humanist chose naturally the *via media* of the Anglican Church as the most reasonable road to salvation.

Professor More gives a scholarly and well-rounded account of Boyle as a theologian, as an alchemist, as a chemist, and as a creative natural philosopher. To do this he had also, of course, to fill in the picture with the rather turbulent political and religious events of seventeenth-century England and with the history of Aristotelian and medieval science. But he has succeeded in subordinating the background to the main picture, and Boyle emerges first as a man and dynamic thinker and second as the one who discovered the law relating pressure and volume of gases at constant temperature. Without minimizing Boyle's epoch-making achievements in chemistry and physics, one may well ask: Which is the more important, actually to discover something new, or to make discovery possible? This life of Boyle is the answer.

It can readily be seen why Professor More (who is also the biographer of Newton) was attracted to writing this biography, for in addition to being a scientist himself he is, as was his brother, the late Paul Elmer More, a distinguished philosopher and humanist-scholar. [An interesting and useful appendix to the book is a reprinting of Paul Elmer More's essay "The Spirit of Anglicanism," germane to Boyle's theology.] As a result he has written sympathetically and with insight of one who advanced human knowledge in many fields.—PAUL H. OEHSER.

TO SEE OR NOT TO SEE

Industrial Ophthalmology. Hedwig S. Kuhn. Illustrated. 294 pp. 1944. $6.50. The C. V. Mosby Co.

It has been estimated that eye accidents cost the American employer over $100,000,000 annually, and the injured workers and the communities in which they live an additional $100,000,000 annually. It has been stated, moreover, that 98 per cent of eye accidents are preventable. In addition to accidents there are certain occupational diseases which exact their toll. Sources of occupational injury to the eyes include: (1) accidents, (2) intense light or heat, (3) toxic substances, (4) inadequate or improper lighting and other abnormal working conditions, and (5) communicable diseases spread by unsanitary work places. Finally, mention must be made of undiscovered and uncorrected defective vision, the magnitude of which is indicated by the results of a number of investigations. In four companies in different sections of the United States, it was found that half or more than half of the workers had defective and uncorrected vision. In one plant three of every four workers had refractive errors needing correction by glasses. The problem of defective vision in terms of production, absenteeism, fatigue, and accident proneness is probably costing worker and employer a sum closely approximating that estimated for eye accidents.

Such in barest outline is the eye problem in industry. What is being done about it? Pertinent in an attempt to answer this question are the results of a preliminary survey recently made with the use of a simple questionnaire mailed to a number of plants. The object of the survey was to determine the status of eye conservation practices. Fifty plants were covered, thirty-two of which employed between five hundred and twenty-five thousand workers each. The results revealed in general a lack of attention to conservation of eyesight as compared with general safety practices. Only a small number of the plants carried out adequate programs for saving eyesight. Job analyses for visual requirements were reported by twelve of the plants. Thirty-five made no tests of the workers' vision or the test made was inadequate. Periodic eye examination of workers was reported by five plants. Prescription lenses were provided for, or required of, the workers in twenty-nine of the fifty plants. Forty plants claimed to supply goggles to workers whom they considered "exposed" while thirty-five fitted the equipment for the comfort of the worker. Eighteen plants issued goggles that had been worn by other workers without a sterilization of the goggles.

Obviously there is urgent need for a comprehensive work on industrial ophthalmology, co-ordinating the essential material on the various problems that confront industry and offering a broad and practical program to meet the needs of industry.

Dr. Kuhn presents her subject under the following subdivisions: visual testing, correction of visual defects for job, visual skills, industrial eye injuries caused by solid bodies, eye protection, and recent developments as related to industrial eye problems. An appendix carries a table of toxic substances and their effects, an all-inclusive eye program for industry, and a standard method of appraising loss of visual efficiency.

The reviewer is deeply impressed, first, by the author's firm conviction that the solution of the industrial eye problem requires the co-operation of other scientists with the ophthalmologist and, second, by the fundamental principle and the fundamental procedure upon which the author chose to base her book. The *principle* is that valid conclusions or recommendations can follow only from the critical assessment of careful and adequate observations. The *procedure* is in essence the "visual job analysis," such an analysis being "the process whereby the component parts of a given job are related directly to the individual visual skills involved in the performance of that job." The adoption of this procedure for fitting worker and job, so far as visual needs are concerned, makes it clear that the old definition of good vision, postulating perfect visual perception, becomes less important, the new definition enunciating that good vision is vision which is adequate for the performance of the tasks presented.

The author shows clearly the various steps leading to fruitful visual job analyses. A job classification list is first secured, this list being supplemented with the precise scope of

each individual job. A trip is made through the plant from machine to machine with someone trained in the mechanical details of machine operations. Pertinent items on what the worker does and on the visual parts of his job are checked on a previously constructed form. These analyses lead to a determination of broad visual admission standards for placement purposes, and to the prescription and fitting of corrected vision glasses or goggles for the job.

The final chapter discusses welding, illumination, epidemic keratoconjunctivitis, general physical health, small plant problems, and the blind in industry.

The book is scholarly, clearly written, and a valuable addition to the growing scientific literature of industrial health. It is replete with suggestions gained from practical experience, of primary importance being those pertaining to the securing of wholehearted co-operation from labor and management. Each of the chapters is followed by a list of pertinent references. The photographs showing various industrial operations were chosen with care. Both the photographs and the typography are kind to the eyes.

The reviewer recommends the book not only to physicians working in industrial ophthalmology but to all plant physicians, nurses, engineers, hygienists, and others charged with the improvement and protection of the health of the worker, and with a better and higher plant production.—W. M. Gafafer.

CALCULUS REFRESHER

Calculus Refresher for Technical Men. A. A. Klaf. viii + 431 pp. $3.00. 1944. Whittlesey House, McGraw-Hill.

In the preface the author states: "The primary purpose of this book . . . is to make available, for ready and rapid use, a "refresher" on the fundamental concepts, methods, and practical applications of simple calculus. . . ." He has succeeded admirably in his purpose. While purists will undoubtedly decry his brevity of theoretical treatment and his empirical viewpoint, technical men who use the book will find that the presentation of the subject is direct and incisive.

The unique feature of the book is the form of presentation—by questions and answers. The questions are well selected, typical of those arising in the everyday application of calculus or helpful in clarifying fundamental concepts. In most cases, appropriate examples follow the answers to the questions, and a list of problems covering subjects treated therein follows each chapter. There is a generous use of the graphical method to illustrate specific points.

The sequence of the presentation is the usual one of differential calculus (Section I) followed by integral calculus (Section II). Also, throughout these sections are placed chapters to "refresh" such related subjects as constants, variables, functions, increments, limits, maxima and minima, types of growth, conditions of logarithmic growth, mean value, center of gravity, and moment of inertia.

Section III is largely devoted to 63 examples of the application of calculus to practical problems. While most of these have an engineering slant (the author is an engineer), yet they range from military construction to bacterial growth. Section III also includes one appendix containing the answers to many of the problems in the first two sections, and a second appendix containing useful mathematical formulas and notations, 201 integration formulas, tables of four place common logarithms, tables of trigonometric functions, and a short table of natural logarithms. There is a nine page index which, although adequate, could profitably be expanded.

The binding of the book is not too sturdy, but the print is clear and legible except for an occasional exponent.

Since it is specifically a calculus text, the book requires a foundation in algebra and trigonometry. Furthermore, although it is well written and devoid of unnecessary details, it cannot by itself "refresh" calculus in ten easy lessons. A serious effort on the part of the user is still necessary.

In addition to serving as a text, this book will also serve well for reference purposes, and it would be a useful addition to the library of a technical man.—S. D. Koonce.

COMMENTS AND CRITICISMS

El Dorado?

In a letter published under "Comments and Criticisms" in the August issue, Colonel E. C. Harwood conveys the idea that the Amazon Valley is a rich, fertile region in which food production can easily be increased. He states: "There is no doubt that modern methods and utilization of land not now producing food (including such vast areas as the valley of the Amazon, now being "pioneered" as our middle west was a century ago . . .) could result in multiplying several times over the present crop and animal products of agriculture."

Food production in the Amazon Valley is being increased and may someday be enlarged to a degree that will no longer necessitate importation of the larger part of its food requirements. But it is far from being the rich, fertile area that many believe it to be. Neither its soil nor its climate is suitable for extensive agricultural development. The Amazon Valley is thickly covered with jungle which yields valuable forest products, such as rubber, chicle, timber, fiber, timbo, nuts, oils, and waxes. However, contrary to the general belief that a soil capable of producing such luxuriant jungle growth must be rich in fertility and suitable for agricultural production, much of the soil in the Amazon Valley is poor. Most of the cleared higher land (land that is not flooded each year) does not produce more than two food crops before its fertility is exhausted. The low lands, which are flooded by the annual rise of the rivers and receive a deposit of silt from the receding waters, are more fertile and can produce food crops year after year. But owing to unfavorable climatic conditions, it is impracticable to make large plantings as the crops must be planted between periods of high water, which brings the harvest during the season of heavy rains. Because of these rains and because the fields would soon be inundated again, the crops must be removed from the fields before they can be cured. With no opportunity to cure the crops in the field, farmers are confronted with the serious problem of drying them artificially so that they can be stored without loss from heating and molding. Even under less humid atmospheric conditions, artificial drying would be an expensive operation, but with the prevailing average relative humidity of 86 per cent during the harvesting season, it is impractical to attempt mechanical drying involving large tonnage with present-known methods and equipment. Small amounts, such as are produced by the average native family on an acre or two of land, can be dried by home methods on platforms with movable roofs or in large heated pans that are commonly used for making farinha.

Due to its poor soil and its unfavorable climate for storage of crops, the Amazon Valley, in my opinion, is not destined to be developed into an agricultural region. The Amazon Valley with its rich forest products was discovered centuries ago and has been "pioneered" by the English, Germans, North Americans, Portuguese, and Japanese. If this Valley had potential agricultural possibilities, these peoples with their knowledge of agriculture, resourcefulness, and capital would have developed it long ago.—T. T. HAACK.

The Ragged Edge

I desire to take this opportunity of asking why the cover pages of THE SCIENTIFIC MONTHLY are larger than the inside pages. It seems to me that it would be preferable to have the dimensions of the cover pages the same as the inside pages, in order to avoid tearing the edges of the cover.—PETER HIDNERT.

We shall endeavor to explain why we think an extended cover on the MONTHLY should be used, although the printers had nothing to do with it originally. We suppose it was the editor's idea, possibly for appearance or for other reasons of his own. However, the MONTHLY should have an extended cover at the present time because the sheets or signatures in an untrimmed book vary so much that it would be almost impossible to cut the cover paper to extend over the largest extended sheet of the book, not knowing how much some sheets extend. The reason for the untrimmed book is that some of the subscribers have their copies bound in volumes after the completion of the printing. If the books were trimmed at head, foot and side when printed, the margins when trimmed again after being sewed for the volume would be very small and out of proportion with the fold and bottom margins. This would be especially true of THE SCIENTIFIC MONTHLY at the present time, since the printed page size has been increased. A larger size sheet of paper should be used if it is to be trimmed all around; which cannot be done at the present time because of the paper allotment.—GEORGE M. HOUCK, The Science Press Printing Co.

Slanguage

I wish to take issue with the man who objected, in your Letters Column of the [SCIENTIFIC MONTHLY], to a flippant bit of slang. The fact that the Association is composed of men of science does not compel it to abhor the common American language. Perhaps one reason why men of science are not able to command anything like the attention for their opinions that they deserve is the fact that they carefully adhere to the King's English—whatever that may be—using a "five-dollar" word where a short word of the American idiom would express their meaning far more clearly.—W. B. SHEPPERD.

Animal Crackers

The article in the July SCIENTIFIC MONTHLY by Alfred Gundersen and George T. Hastings, "Interdependence in Plant and Animal Evolution," was most interesting. It seems hardly proper to pick flaws in so stimulating a paper, but it is rather unscientific to speak of the duckbill as "intermediate between birds and mammals" (p. 68), descriptive superficially as that might be. It shows reptilian characters of importance, but the bill on which such stress is laid by this statement is without doubt an independent development, like that of the duckbill dinosaurs. On the same page it is implied that Archeopteryx was supposed to feed on fish, whereas the interpretation of the authors that it fed on fruits is more usual, on the other hand the toothed Cretaceous birds probably were fish-eaters. The teeth in these two groups are quite different.

On page 70, the lemurs are said to have some marsupial characteristics; stated in this broad way any mammal might be said to have such, but the special characteristics shared with marsupials do not come readily to mind. On this page the addition of a word would have helped the sentence "Carnivora generally have multiple births, but among [the larger] herbivora. . . ."—JOHN ERIC HILL.

The Grapevine

I have noticed that in your excellent journal you occasionally give space to articles intended to extend your readers' knowledge of the natural history of our amazing earth. Frequently these have had to do with the science of botany. Therefore, I am led to submit the accompanying piece on one botanical subject on which I have seen virtually nothing in print, in the hope that although it may not be said in any way to advance the science of botany it may nevertheless indicate the author's profound admiration for the indispensable member of the Plant Kingdom referred to. Botany, I have often thought, is perhaps after all the greatest of all the sciences, since man's dependence on plants is so great as to be really breathtaking, as well as dreadfully humiliating. May I add that I was brought up on a grape farm in western New York State and can claim some intimate knowledge of viticulture:

I am a plant, a lowly plant,
  Of leaf and flower and bark and root;
And though I'm not too elegant,
  I bear such good and gorgeous fruit.

My botany's beyond discredit.
  My family? Vitaceae.
Who would not dearly love to edit
  My long and luscious history?

I am the faithful old Grapevine,
  Whose tendrils pass through stone and brick,
Along dark hallways serpentine—
  No wall too steep or high or thick.

Men tap my strength, nor question source,
  Whether it came from here or yon,
And when replete with facts, of course,
  I help to pass them on and on.

I little care what people say;
  I have no fears; I'm never tearful;
For what I do I ask no pay,
  But give them all a gratis earful.

When minds, both lay and scientific,
  Get thin and dull, and news is slow,
'Tis then my speed becomes terrific—
  Fleeter than wind or radio.

So fast am I that, strange enough,
  Often the event pursues the word,
And news of it becomes old stuff
  Long, long before it has occurred.

Such sure and quick communication
  You'll have to travel far to find . . .
I am a blessing to the nation,
  A benefactor of mankind!

—PAUL H. OEHSER

THE SCIENTIFIC MONTHLY

OCTOBER, 1944

WORLD MAPS

By REAR ADMIRAL G. S. BRYAN

The average man has never taken his geography very seriously. It is a subject which he completed in his elementary schooling and then packed away in moth balls to be resurrected only when something important happened somewhere and he wanted to know where that particular spot was.

Something important has happened in a good many unheard of places in the past few years. Attu, Guadalcanal, Tobruk, Chungking, Kharkov, Truk, Salerno, and numerous other names have made headlines which have left the average man in a geographical daze. The result has been a revival of interest in geography and a desire not only to find out something about each of these places but also to visualize these various theaters of operation in their proper relation with each other so as to give a broad general view of the conduct of the whole global war. In short, the public is now brushing up on its geography and is paying particular attention to the study of *world maps.*

Cartographers have recognized this trend and have been examining the situation to determine what can be done to improve present world maps. A number of discussions on the subject have been published recently in books, magazines, and even advertisements. Some of these articles are very good; others show a startling lack of fundamental understanding of the subject. Nearly all the latter condemn the most popular world map, the Mercator (Fig. 1), as obsolete, but few of them have anything new to offer in its place.

Let us define a map as a conventional representation of the surface of the earth as developed on a plane surface. The geometrical, or mathematical, method of accomplishing this is known as the projection. The term 'world map' as used in this article refers to a single map which covers all, or nearly all, of the world. The so-called Mercator world map is included in this definition.

What we should really like to have is a world map that shows the component parts of the earth in their relative sizes, shapes, locations, and directions. Since it is only on a globular surface that we can fulfill all of these conditions, it is apparent that if we insist on representing the whole of the face of the earth on a plane surface, we are going to get a very distorted picture. We are not surprised that we do not obtain any great accuracy; on the contrary, we are astonished that we can attain even an approximation. It seems to be a fairly easy matter to skin a bear and make a flat rug out of his hide, but flattening a globe presents a more difficult problem.

The ingenuity of cartographers has been taxed for centuries to meet the problem of developing a projection which will come close to fulfilling the conditions previously mentioned. This can be readily accomplished on maps of small areas where the curvature of the earth is small. For large areas, however, it is only possible to satisfy approximately one or two of the requirements usually demanded and even then only at the expense of distortion in other respects.

Both the character and extent of the distortion of a map vary with the type of projection used. Both of these also vary with the size of the area covered. Unless this is kept in mind, comparisons of different projections will be decidedly unfair. We are all familiar with the classic example of distortion that is constantly raised against the

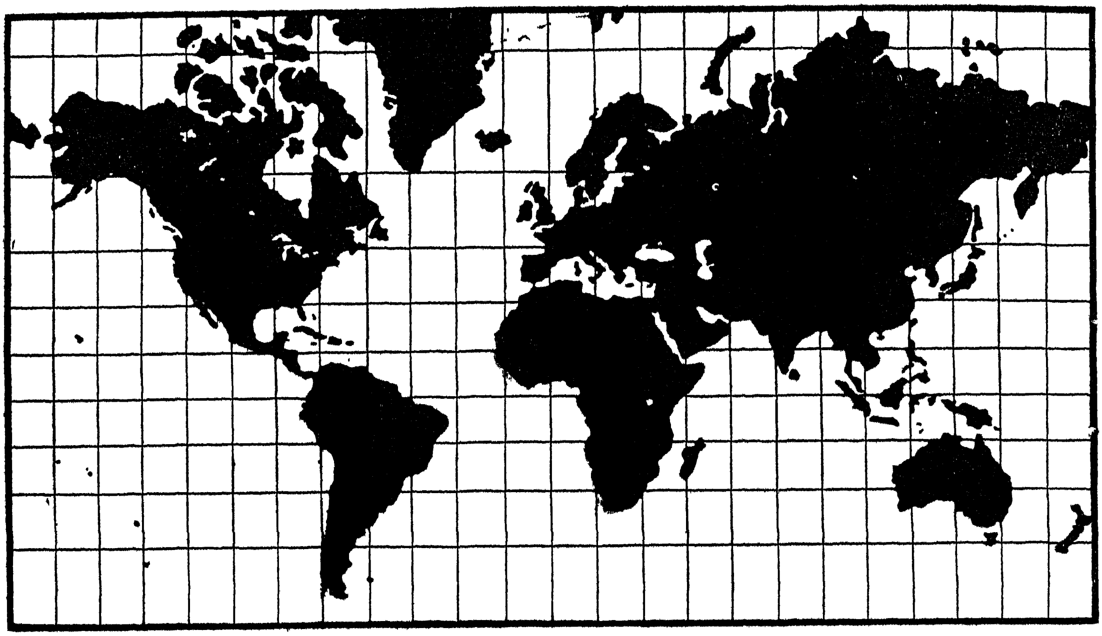


FIG. 1. MERCATOR PROJECTION

Mercator projection; namely, the disproportionate areas of Greenland and South America. On the basis of this comparison some extremists even refer to the Mercator as "falsifying" geography. And yet these same authorities recommend the use of the polar azimuthal equidistant map of the world (Fig. 2) to replace it, blandly ignoring the fact that the relative sizes of Greenland and Antarctica on this map are even more greatly disproportionate.

We can consider the various types of projections in the same way that we do a set of tools. A saw is a very handy implement but it is of little value for driving nails. Similarly we might say, for instance, that the gnomonic projection is an excellent one for laying out a great circle track but is of little value for comparing relative areas or shapes.

In selecting a projection we should therefore choose one whose characteristics best fit our purpose. For instance, if we want to compare certain areas as to the extent of cultivated land, some equal area type of projection would be best. If we require a chart for navigational purposes, we want the projection on which a compass course shows as a straight line—the Mercator. If we wish one on which we can measure accurately the bearing and distance from a single point, the azimuthal equidistant projection will be the most suitable.

There is no real substitute for a globe for the study of world-wide geography. However, globes take up a lot of space. No more than a hemisphere can be seen at once and its periphery is necessarily out of focus and distorted. In order to use a globe for world-wide coverage, it must be revolved for successive examination of areas of interest.

On the other hand, a world map does show the entire world in a single view. On a wall it takes up very little space and is always readily available. With all its technical faults it is convenient to use and for that reason world maps will remain in demand for use in schoolrooms, offices, and homes for ready reference purposes.

What kind of world map is best for general reference? The geographer or the statistician would probably stress an equal area or conformal type; the navigator would prefer the Mercator projection. They are specialists, however, whereas we are trying here to select a type of map that will find favor with the nonspecialists—the average man who knows little or nothing of projections but

who does like to enlarge his knowledge of geography occasionally by referring to a map of the world.

The interest of the general public lies, by and large, in the location of a particular place, in areas adjacent to it, and in the relative location of other places; that is, their approximate distance and direction from it. People also like to know how the mountain ranges run, the approximate altitudes of mountain peaks, the size, length, and direction of flow of rivers. They are interested in the various land, sea, and air traffic routes.

The relative sizes of different areas are, of course, of interest, as is the feature of exact shape, but great accuracy is not usually demanded. The same applies to distance. The average person rarely makes a careful measurement of distance on a world map and is usually satisfied with an approximation that is apparent to the eye.

The plotting of the shortest (great circle) distance between two points as a straight line is desirable, but this feature is impossible to obtain even approximately on world maps. Important great circle routes are often plotted as curves on maps of various types. This falls short of what is desired and is somewhat

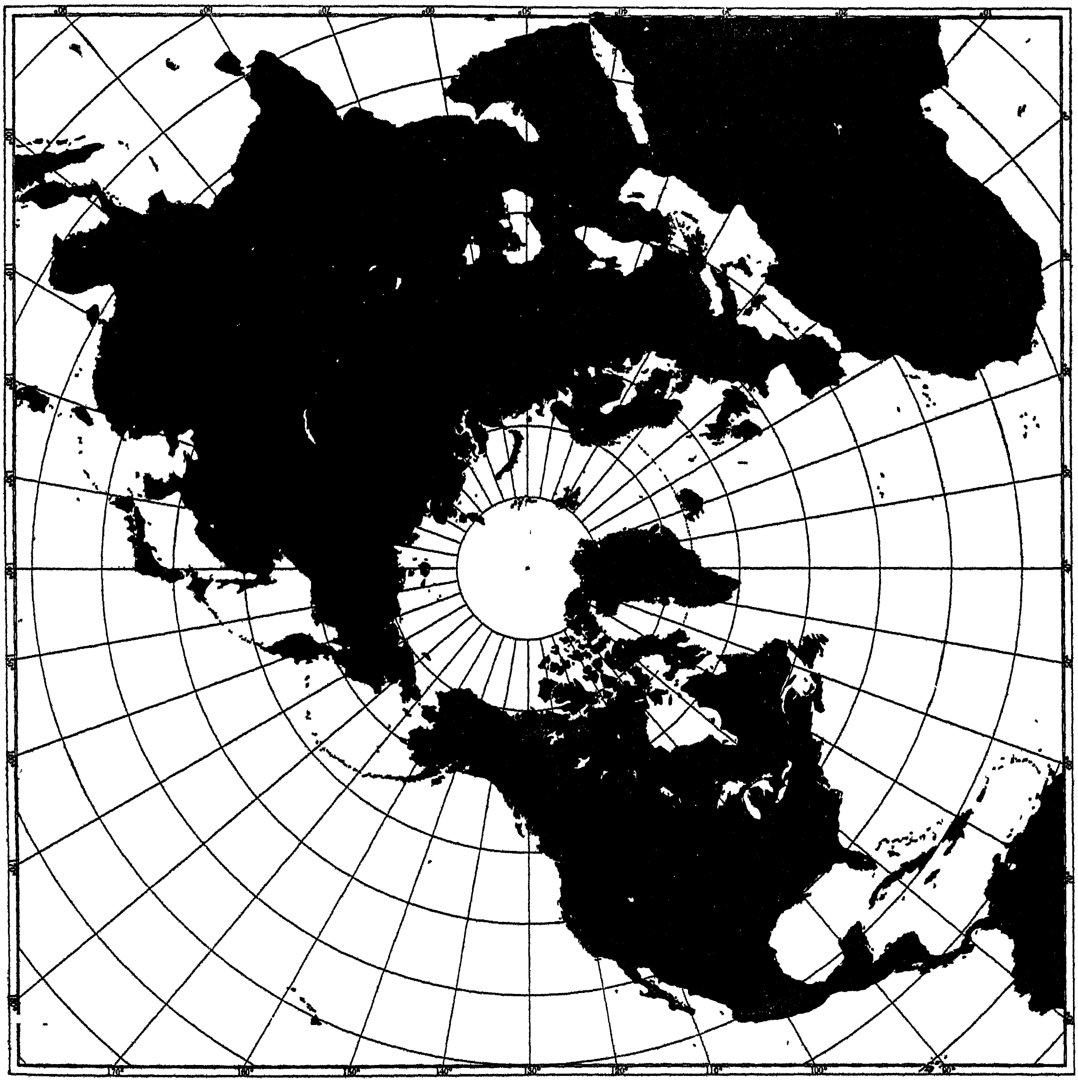


FIG. 2. POLAR AZIMUTHAL EQUIDISTANT PROJECTION

confusing to the uninitiated, but this procedure is probably the best compromise that can be made without sacrificing too much in other directions.

Continuity is another characteristic that is desired by the casual map user. Complete continuity can, of course, be obtained only on a globe. Nevertheless, we expect our maps to be such that we can follow from one place to another readily without jumping frequently across blank sections of paper. The average map reader is perplexed as to both the direction and distance between any two points when a line joining them crosses an interruption.

While the average man is not quite so exacting in his requirements as are the specialists, he still wants much more in a world map than cartographers can give him. Let us examine the principal types of projections to see how well they can fulfill his demands. Only a few types of projections actually cover the entire surface of the globe and we will start with these.

Ellipsoidal projections, such as those of Aitoff, Mollweide (Fig. 3), and Van der Grinten, give perhaps the closest approach to an equal area world map. These types cover the entire sphere. They show considerable distortion and lack of conformality and they lack continuity around the perimeter. While they give a good generalized picture of the world, they are not well adapted for showing direction, either great circle or rhumb line.

Devised within recent years are a number of types of world maps which can be folded closely around a globe and which can also be spread out flat to form a map. Cahill's butterfly map and Goode's homolographic map are samples of these and within the past year or so, Buckminster Fuller's dymaxion map and Professor Irving Fisher's icosahedral (or polygnomonic) map (Fig. 4) have been added to the list, the last one, in my opinion, being by far the best of this type.

The principal advantage of these types is that they can be folded to approximate a globe, and then by spreading them out flat the relationship between a globe and a map can be studied. For instruction purposes in the schools, these maps should be very useful. Their principal weakness when used as flat maps is their lack of continuity. Either a compass course or a great circle will change direction at the edge of each section. The bewilderment of the average man in trying to bridge the interruptions of these maps will disqualify them as popular world maps.

The other principal type of projection covering the entire world is the azimuthal equidistant projection. This type is usually seen as a polar map for which it is particularly well fitted. The United States Hydrographic

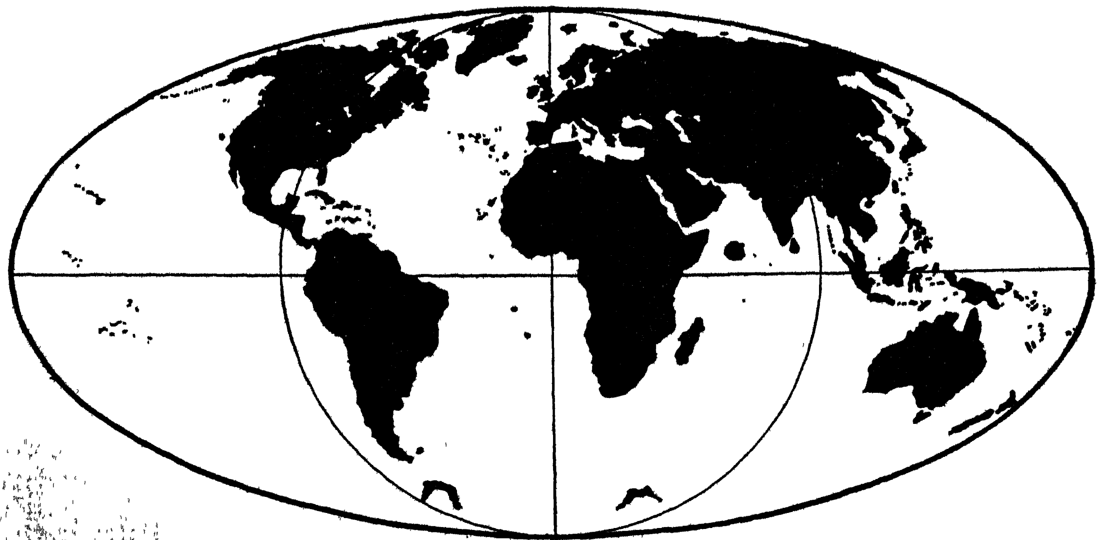
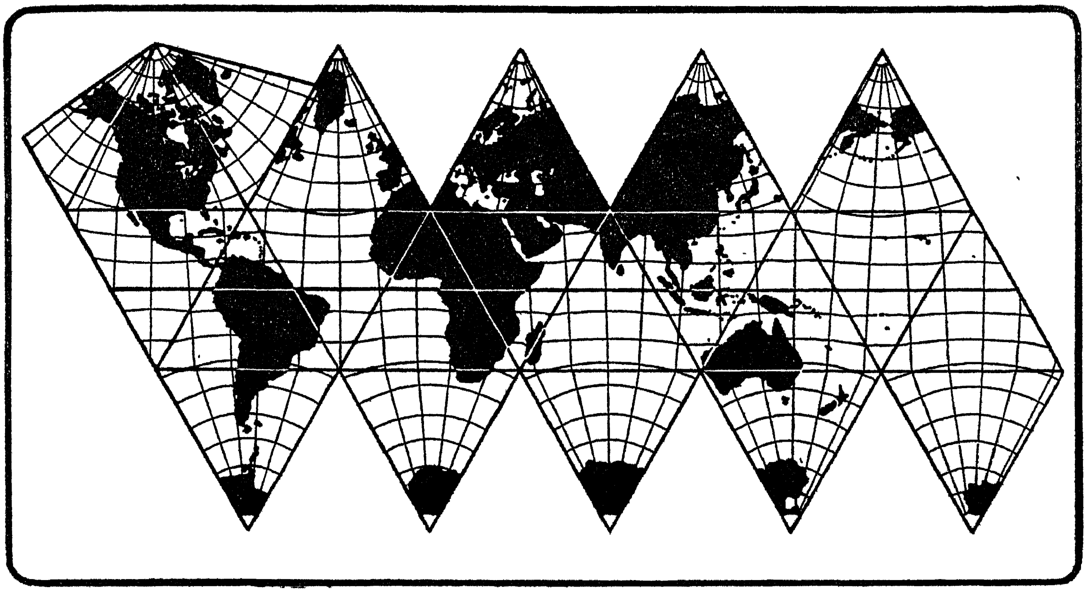


FIG. 3. MOLLWEIDE'S HOMOLOGRAPHIC PROJECTION



Courtesy of Prof. Irving Fisher

FIG. 4. FISHER'S ICOSAHEDRAL PROJECTION

Office published two world maps of this type which are centered on Washington and San Francisco respectively, but these were prepared for a special purpose and not for general use. The Hydrographic Office also uses this projection for charts of the polar regions.

This projection gives a fairly good portrayal of the earth's surface for a single hemisphere, though it is neither conformal nor equal area. The distortion and change in the distance scale are at least within reason when confined to a hemisphere, but when coverage is extended beyond this point, the distortion increases greatly until the opposite pole becomes the perimeter of the circular border.

This is the map which has been so widely publicized lately as the "Air Age" map, which is supposed to open a new era in geography and to make other types of world maps obsolete. According to some of these authors, the principal air routes of the future will lead across the vicinity of the North Pole, and this type of map will be necessary to show them correctly. Some authors have even claimed that straight lines on this map approximate great circles, although this is true only for a limited distance from the central pole.

Most of the other forms of maps that cover the entire world are variations of the preceding types, or at least they resemble them to a great extent. Most of the better-known projections, such as the polyconic, Lambert, conformal conic, and gnomonic, are not adaptable for coverage of the entire world or even approximately so.

The most popular of the so-called world maps is that on the Mercator projection. Strictly speaking, this is not a real world map because it cannot be extended to the poles. It is conformal and is continuous in an east-west direction, lacking continuity only in the polar region. Areas in the high latitudes are greatly exaggerated as compared to those in the low latitudes. It gives a fair representation of the world up to about 60 degrees latitude but beyond this, a rather distorted picture results. The distance scale varies with the latitude.

Although this projection is usually preferred for world maps by the general public, it has never been a favorite with geographers and cartographers. Some class it as the "terrible Mercator" and others even demand that it be eliminated from use in the schools. Most of this objection is based on distortion of scale in the high latitudes.

The Mercator, however, has two qualities

which make it the standard projection for navigational charts; first, the use of a rectangular system of plotting latitudes and longitudes, and second, the ability to represent a true compass course as a straight line. Of course, the straight line does not represent the shortest distance between two points, for that is a great circle track. When it appears desirable, however, to show great circles, they can be plotted as curved lines on a Mercator map and this is a rather common practice. Many Mercator world maps show these tracks between the principal commercial centers.

Although the Mercator projection was especially designed for navigational purposes, it has also proved to be the most popular type for world maps. There are two principal reasons for this. First, this map is continuous in an east-west direction. At one edge of the map we can transfer easily to the same spot on the other edge and continue on indefinitely. Of course, there is no continuity in a north-south direction. However, if the Mercator map is limited between 65 degrees north and 50 degrees south latitude, practically all the important inhabited areas of the world are included, and all the commercial routes can be seen except those passing north of Norway and Siberia.

Second, the Mercator map shows a true compass course as a straight line. Most geographers or cartographers will doubtless prefer to have a straight line represent a great circle. No map of the world, however, will show all great circles as straight lines or even approximate ones. The navigator still clings to his Mercator chart, plots his great circle track on it as a curve, and then follows this curve approximately on a series of chords of constant compass courses. Which is the more important to the layman, a straight line to represent the shortest distance or a true compass direction?

The average person knows little or nothing of great circles and rhumb lines. When he faces north and points 90 degrees to his right, he believes that if he should continue in that direction in a straight line he would be heading steadily east. If he is in New York, for instance, and points east, he feels that he is pointing towards Madrid since these two places are approximately on the same parallel of latitude. Any attempt to show him that this is not true only serves to confuse him.

If one tries to explain to him that the direction in which he points is a great circle whereas a constant easterly course will follow along a parallel of latitude, he will inquire, "Then what direction is Madrid from New York?" One can, of course, temporize by saying that it all depends on what is meant by *direction,* but probably the better answer is to say that a steady easterly course from New York will lead to Madrid, but a continually changing compass course along a great circle track will also terminate there and in a shorter time since the distance is less.

That one must follow a continually changing course to travel the shortest distance is much too complicated for the layman to appreciate, but it is quite simple to understand that one can follow a single continuous true compass course and still get there. After all, since he never expects actually to make such a trip, why should he tax his brain to understand just what it all means? But if he is told that there is one particular type of map on which a true compass course is represented by a simple straight line, he is going to prefer that type of map, and leave the cartographers and navigators to struggle with their great circle problems.

This, I believe, is one of the fundamental reasons which accounts for the popularity of the Mercator map of the world. It saves the casual map reader from having to do a little thinking. Critics may argue that this results in giving him a false impression and that he should be taught the true situation. Perhaps this should be done—particularly in the schools. However, as long as we have a general public more or less uneducated in this particular phase of the subject, there is going to be a demand for the Mercator map of the world.

Certainly no single projection is going to give us a world map which is satisfactory for all purposes, or even one that is satisfactory for general public use alone. Apparently we shall have to reach a broad compromise at best among the various qualities that are required. Each projection has some of the

desired features but lacks others, or even possesses some which are objectionable. For a straight pictorial representation, Mollweide's appears about the best, but this falls too far short in other directions. The problem of the cartographer to devise a world map on a single projection appears intractable, as one well-known authority has expressed it.

Can we solve this problem by using two separate maps? There are, of course, the "two hemisphere" types. The orthographic projection gives us two bird's-eye views of a globe, but each of the two hemispheres is badly distorted at the edges. The stereographic projection gives a fairly good map of a hemisphere (Fig. 5). Both of these projections, however, lack the continuity that we require between the two hemispheres.

Two polar hemispheric maps on the azimuthal equidistant projection also give slightly better coverage than the stereographic but they also lack continuity across the equatorial belt. The same can be said of any conic projection of a hemisphere. If we must have a lack of continuity, it should preferably be in those regions where we least need it; that is, around the poles.

Since the two polar hemispheric maps appear to give generally satisfactory coverage of the world except for continuity in the equatorial regions, and since the Mercator projection also is quite satisfactory except in the high latitudes, it appears that a combination of these three should supply about the best compromise that we can obtain for world-wide coverage.

The central section of this combination on the Mercator projection should extend from 72 degrees north latitude to 60 degrees south latitude. The northern limit is rather high for the Mercator projection but it is carried this far in order to take in the northern tips of Norway and Alaska. In this way, long range continuity can be obtained on one map between practically all of the inhabited areas of the globe, when this is wanted.

The two polar maps should extend from each pole to 20 degrees latitude. This would give continuous coverage over the major portions of each polar hemisphere. The azimuthal equidistant projection appears to be best suited for these polar maps. The scale for these maps should be the same as that of the Mercator map at 30 degrees latitude. Curves indicating the scale at the different latitudes should be shown on the bottom margin of the Mercator.

The combination of these three maps will give a rough visual representation of the relative sizes, shapes, distances, and directions, and of the routes over the entire world. It is not claimed that even approximate accuracy will be obtained when careful mea-

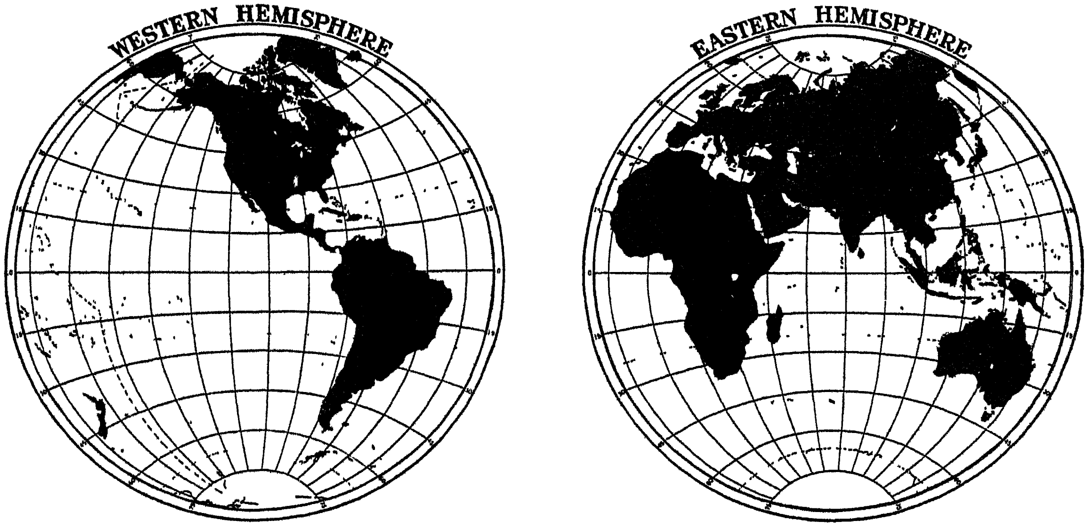


FIG. 5. STEREOGRAPHIC PROJECTION

surements are wanted, but world maps are seldom used for this purpose. To the average man, a visual approximation is sufficient. The same also applies in the schoolrooms.

There remains the question as to which of the three maps should be used for our various purposes. Where they differ, which one is to be given preference? Both projections are fairly good as far as conformality is concerned. For purposes that require a comparison of equal areas, the polar chart is the better. In the equatorial belt, which is covered by the Mercator alone, comparisons may be made of areas with others on the polar map without any great exaggeration being apparent.

Distances can be measured or estimated on any of the three maps according to the scale diagrams as printed on it. Great accuracy is not usually required on world maps, nor, may I add, is it usually obtained. It should be remembered that distances measured on the Mercator represent those along a rhumb line and not along a great circle. In the equatorial belt these two lines are almost identical.

For true compass courses, the Mercator is, of course, the best. For great circles, the best solution is to have them drawn as curves on the Mercator map between the principal commercial centers of the world. In the high latitudes and across the poles, the polar chart would have to be used, and here a straight line approximates a great circle.

The polar maps suggested here were not selected to accord with the theory of the "Air Age" enthusiasts that air routes of the future will cross the bleak regions in the vicinity of the poles. A study of either a polar map or a globe will show that few, if any, air routes will extend beyond 70 degrees latitude. At least 3,000 miles of frozen waste lands or floating ice must be crossed if one flies across the poles, with no place available for landing and refueling. Surely a great saving in mileage must be evident to compensate for this handicap.

Try to pick a route in which such a saving is made. Opposite the United States and across the North Pole lie the frozen wastes of northern Siberia; opposite the thickly inhabited areas of China and Japan lies the Atlantic Ocean; and opposite Europe lies the broad expanse of the Pacific. Apparently the world was not laid out with a view to the use of polar routes. The polar maps will serve a good purpose, however, for those routes that extend into the high latitudes even if they do not go within a thousand miles of the pole. At least, these routes can be better visualized on this map than on the Mercator.

The conclusion that a combination of three maps is the best solution of a satisfactory world map was arrived at as a result of study and analysis of this subject. However, no originality is claimed for this conclusion. If the reader will consult some of the old atlases of the seventeenth century, such as those of Hondius, Jannsen, or Blaeuw, he will find the then known world similarly portrayed on the Mercator projection, with the addition of slightly smaller maps of each pole on an equidistant polar projection.

THE PROBLEM OF ORGANIC FORM*

II. COMPETITION AS AN INTEGRATIVE FORCE

By S. J. HOLMES

FROM the time of Adam Smith to the present, multitudes of writers have dwelt upon the beneficent role of competition in coordinating the economic and various other activities of the social organism. Along with other benefits competition obviously affords an effective spur to diversity of occupations. Where too many people are engaged in the same pursuit they seek relief from pressure by finding new employments. But the employment chosen must contribute something to the corporate life, else it would receive no reward. As a rule occupations are not followed entirely from choice, and the organization of economic life is not, or at least need not, be consciously planned. Through the supply and demand relationship it operates in a socially adaptive manner of its own accord. If there is a shortage of carpenters, the pay of carpenters increases; labor which is under the pressure of competition elsewhere flows into the partly unoccupied field and brings about a restoration of its depleted ranks. A result akin to regeneration in response to economic needs is thus brought about through the automatic operation of a sort of *vis medicatrix naturae* of the social body.

By putting a premium upon diversity of occupations, competition aids in securing the advantages accruing from the division of labor. Competition makes for diversity because, if I may speak figuratively, life is continually endeavoring to escape from it. In organized society the avenues of escape normally lead to activities requiring mutual aid and co-operation. Societies are mutual benefit associations and they tend to engender an altruism among their members that is quite closely subordinated to the egoistic interests of the group as a biological unit. One great advantage of social life is that it secures the benefits of competition and co-operation at the same time.

Can we apply the same principle to the individual organism? There is a widespread suspicion of parallels between individuals and societies. But a number of these analogies spring from the common properties of life. Both individuals and societies are composed of smaller units with the power of growth by assimilation and multiplication. In fact, increase in both cases is really the same biological process. In both cases competition must result from many of the same causes. In both cases there is a division of labor that makes for the preservation of the whole; and in both there is co-operation of component parts. It may be said also that there is competition between co-operating elements and that this circumstance would in both cases make for a balancing or automatic adjustment of activities.

The attempt to apply the concepts of competition and selective elimination to interpret the formative processes in individual organisms was first systematically undertaken by Wilhelm Roux in his brochure *Der Kampf der Teile im Organismus*. These processes exhibit many striking direct adjustments to meet departures from normality which vary from slight injuries to the loss of entire organs. Since contingencies never before encountered in the history of the race are continually met by appropriate adjustments, it was contended that they could not have been provided for in all details by natural selection. How can such apparently purposive behavior be explained? Being a mechanistic biologist strongly opposed to the theories of vitalists, teleologists, *et hoc genus omne,* Roux bethought himself of a way of meeting the difficulty by extending the principle of selection to the component parts of the organism. Roux held that the parts of an organism are engaged in a struggle ranging from organs, through tissues and cells, down to the ultimate self-perpetuating units of which, in common with numerous biolo-

* Continued from p. 232 of the preceeding issue.

gists of his day, he conceived living matter to be built up. Since these living units were supposed to grow and multiply, they would inevitably compete, and those variations among them which are better fitted than others to cope with the particular conditions that affect them would gain the upper hand and bring about a better adjustment to their environment. Roux laid great stress on the application of his theory to explain functional hypertrophy and atrophy, and he advanced much evidence to show that these processes play an important role especially in the functional period of development.

That struggle occurs between cells would seem to be a reasonable deduction from the fact that they are more or less individualized units with the power of growth and multiplication. In a starving planarian or Hydra, which may become reduced to a small fraction of its original size, there is an enormous elimination of cells along with the maintenance of an approximately proportional representation of the various organs and tissues. Under these conditions a lively intercellular struggle would seem to be inevitable.

That the struggle of its parts suffices to give a satisfactory general explanation of the direct adaptations of the organism is, however, open to serious question. We may take as an illustration a phenomenon by which Roux was strongly impressed and which seemed to him to be entirely inexplicable by the ordinary Darwinian theory. The lamellae of bone are so disposed as to provide the maximum resistance to the stresses and strains to which they are exposed. Where bones are broken and grow together in an abnormal position, the lamellae are directed so as to meet the new demands. Such cases, it was urged, cannot possibly be explained by the elimination of individuals among the ancestry. The adaptation is direct and not specifically provided for by heredity. A similar reaction is given by connective tissue which lays down fibers in the direction of greatest tension. It is shown experimentally that connective tissue subjected to new strains responds directly by developing fibers which resist the strain. Roux attributes these reactions to functional stimulation which causes a specific kind of hypertrophy. But he goes further and attempts to account for this kind of functional hypertrophy as a consequence of the struggle of the parts of the cells involved. Somehow, he thinks, those units prevail that react so as to meet the situation. But in these direct reactions of connective tissue and its derivatives we are dealing with a general mode of reaction, the production of fibers or lamellae in the direction of strain. Given this general mode of reaction to strain, the cells could make adaptive reactions to many varied and unusual contingencies.

In these adaptations there is reason to believe that the apparently teleological behavior is a direct consequence of the physical and mechanical properties of proteins quite independent of any supposed struggle of their postulated units. There are fibers formed in gels and their arrangement may be determined by stretching. It is significant that collagen, which is a protein occurring abundantly in connective tissue, responds to a pull by arranging its fibers in a way that might be regarded as a direct adaptation.

That organs increase through use and diminish through disuse may be susceptible of a purely physiological explanation without involving any internecine warfare among the vital units. Owing to this relation to functional stimuli, parts of the organism may within limits adjust themselves to the requirements of the organism as a whole. Roux's adherence to the doctrine that living protoplasm is made up of minute units intermediate between molecules and cells often led him to assume the existence of selective survival where there is little evidence that such process really goes on. As matters work out in the living body, struggle commonly leads to balanced activity instead of elimination. But as to how the organism solves this problem Roux is far from clear. The organic mechanism as he conceived it lacks a balance wheel.

Very often the struggle for existence is merely destructive. In an aggregate of independent units it commonly leads to homogeneity through the extinction of everything except the strongest. But within an organized society or an individual it may work out in an entirely different way. And why? This is because the parts of a society and of an individual organism stand in a relation

of mutual dependence. Where a part receives from others materials or stimuli required for its life, it cannot increase to the extent of injuring other parts without automatically incurring an injury to itself. Each part of a living aggregate has a primary tendency to extend itself and compete with others. It is this tendency which at least in part leads it to increase its activities when they fall below the rate required for supplying the other parts. This egoistic self-seeking is thus an indispensable factor in securing a balancing of functions. The checks elicited when this functioning or growth exceeds certain bounds are equally indispensable. Between the two an organism, individual or social, tends to settle into a state of moving equilibrium. *The process of expansion which leads to competition thus works as an integrative force when it takes place between mutually dependent parts.*

In this simple fact we have a principle of fundamental importance in relation to the regulation of organic form and function. Under these conditions Roux's conception of the struggle of parts leading to the elimination of this or that variant kind of unit, whether living molecules or cells, would have a relatively limited sphere of application. Most struggle among the parts of an organism, as among the individuals within a society, stops short of the lethal stage.

Two of the basic problems that confront one who attempts the formidable task of analyzing development are (1) the problem of divergent differentiation and (2) the problem of the proper arrangement of parts. It is obvious that the formation of a lot of differentiated cells and tissues could never produce a viable organism unless these parts were arranged in a very special manner. How do they come to occupy the right places at the right times? Weismann's attempt to explain divergence and proper placement as a consequence of qualitative nuclear division got him into all sorts of trouble and since it is now completely rejected, it requires no further comment. Nor need we linger over the germinal area theory of His and his appeal to undulations to account for the initial germinal map. The crystal analogies are too vague and general to be of much assistance, and the theories of gradients and of formative fields are in much the same boat. Personally, I am convinced that if we ever arrive at an adequate interpretation of morphogenic processes it will be through a study of the functional relationships of the parts of a developing or regenerating organism.

If we regard differentiation as a consequence of continued balancing, our two basic problems of divergence and proper placement are not two but one. We must assume that as a rule it is placement that causes divergence, and that divergence results from evocation in response to a localized situation. The stimulus complex varies with the local area, and out of the many possibilities of reaction afforded by its many genes a cell reacts differently in different regions of the developing egg. To the question as to why the response is a fitting one adjusted to the needs of the whole, one may say that it is a consequence of forces analogous to those by which socially valuable adjustments are unconsciously made in the social organism. These flow from the supply and demand relationship in which competition enters as a component factor.

In the course of evolution the kind of variations that dependent parts would tend to accumulate would be those which check the activities of associated parts when these exceed a certain norm of intensity. The role of inhibition in co-ordinating the functions of the adult body is generally familiar. It is manifested in the regulation of the heart beat, the secretion of many glands, and the co-ordination of many functions carried out by several organs. There are substances given off by certain organs which are definitely inhibitory in their action on other parts, and the integration of the adult body is dependent upon their influence. If some organs receive accelerator and inhibitory nerves which give off their different chemical stimuli, it is not unreasonable to suppose that various parts in the early embryo receive both accelerator and inhibitory substances from their near neighbors, and that these act as automatic balancers of functioning and formative activities.

Most vital activity consists of responses to the organism's own stimuli. That these responses should effect the development of a complex and harmoniously functioning whole

is possible only if the process starts with a bit of living matter having potencies for making many kinds of adaptive reactions and that these change from stage to stage. This credits our bit of living matter with stupendous, almost miraculous, powers. But so long as they are not quite miraculous, like entelechies, this is nothing against the supposition. The bit of living matter does almost miraculous things. Hence any theory of development seems almost staggering when we try to imagine its operation in detail. If we conceive the complexities of development with all the regulation it involves as flowing inevitably from the constitution of the fertilized ovum, we have brought the problem of the teleology of the individual to the constitution of the germ plasm and thereby handed it over to the phylogenist. If the phylogenist is an orthodox Darwinian, he would account for the evolution of the germ plasm through the slow accumulation of favorable variations of developmental responsiveness. Roux and other students of direct adaptation were greatly troubled over what they deemed the inadequacy of the phylogenetic explanation of new and often resourceful means that organisms employ to attain normal wholeness. They felt compelled to seek some other way of explaining teleological behavior. But the situation was really not so bad as they imagined. Natural selection does not endow the organism directly with this or that structure, but with ways of making morphogenic responses to stimuli. The structures produced are incidental upon the reaction modes of the species. Hence many new adaptive modifications in the arrangement of connective tissue fibers, bone lamellae, and other striking exhibitions of purposive behavior are as explicable in terms of selection as is tough hide or protective coloration.

But, as we have contended, there is a justification for Roux's conception of the struggle of the parts in ontogeny. He did not conceive of it as a struggle between mutually dependent parts, although like all other biologists he talked about this interdependence. He did not combine the ideas of struggle and dependence in a way that would throw light on the organism's capacity for self-regulation or point out that, while struggle between independent parts would lead to homogeneity in this or that cell and would probably wreck the whole organism, the struggle between parts that are mutually dependent makes for an automatic self-regulation of functions. The numerous reaction modes which I have mentioned as having been picked up during the long course of evolution have been to a large extent responses that secured the advantages of better cellular and organismal co-operation. The genes have had a long discipline through selection for the various parts they play in the drama of embryonic development. Directly or indirectly they set up processes which tend to go on increasing and hence sooner or later interfere with one another's expansion, but during their evolutionary history they have become dependent while securing the advantages of essentially social relationships. Through these relationships, like the members of a society, they automatically regulate their affairs.

III. THE PROBLEM OF DIVERGENT DIFFERENTIATION

One of the most conspicuous features of embryonic development is that cells originally very much alike become transformed into nerve, muscle, gland, and other kinds of cells of the most dissimilar form and function, and that they produce very different chemical substances of which not the least trace can be found in their simpler progenitors. We commonly try to explain differences as consequences of previous differences and carry the process back as far as we can go. We might conceive of an egg whose cytoplasm is devoid of all regional diversity. Some inequality of environmental influence might set up a primary polarity and something else might determine the plane of bilateral symmetry. Surface tension may cause the outer protoplasm to as-

sume properties different from those of the interior, and metabolic products which are immiscible may segregate like oil and vinegar in French dressing. Visible differences are often brought about in early development through the flow of materials. In the frog's egg the inward migration of peripheral pigment causes the formation of the gray crescent commonly opposite the entrance point of the spermatozoon. The egg of *Styela* shows an extensive streaming of both clear and yellow cytoplasm to their definitive positions. During the early development of many eggs, materials become more sharply separated out. One may say that these eggs become more or less unscrambled preparatory to undergoing further development.

Embryonic development, however, can be accounted for only in small part by initial polarity, surface tension, and other factors to which we have referred. Aside from these factors there must be some very potent force compelling chemical processes to run in different directions in various regions of the developing egg, so that, out of a relatively homogenous chemical matrix, we finally get a highly diversified aggregate of chemical factories. Why this great urge to chemical diversification?

The phenomenon is the more remarkable because it would seem that the natural tendency of chemical activity would be toward uniformity instead of diversity. In any fluid medium the prevalent tendency toward chemical equilibrium would be to overcome divergence. Differences of composition, once established, might be maintained by semipermeable membranes. But, however numerous may be the compartments so separated, the tendency of the system would be to settle into a static condition as uniform throughout as the walls of the compartments would permit. Vitalists have often urged that chemical forces alone would effect the dissolution of living matter, and that their influence is overcome only through the constructive vital activities of the organism. Life has been looked upon as an upbuilding force, like Vishnu, the Preserver, continually at war with Siva, the Destroyer. But, as Claude Bernard has pointed out, the co-operation of Siva is quite as necessary as that of Vishnu in the process of living. And now, since the discovery of the synthetic function of enzymes, Vishnu and Siva have turned out to be the same person.

An aid to the maintenance of chemical diversification is afforded by the fact that the semipermeable membranes of living protoplasm have selective and variable permeabilities by which they function in a manner different from the membranes of most nonliving materials. An individual egg is a mass of protoplasm, partly gel and partly sol, with numerous interstices within the framework of more nearly solidified jelly. The nucleus contains many varieties of genes which produce many kinds of enzyme action, both synthetic and destructive. The more fluid part of the protoplasm contains salts, dissolved carbohydrates, proteins, lecithin, fats, hormones, vitamins, and various other chemicals. Throughout the cytoplasm are many little chemical factories in which changes go on, resulting in oxidation, secretion, fermentation, and other processes the products of which may be selectively transuded to other cells or to the outside of the organism. The gelled protoplasm constitutes a sort of framework within the interstices of which the metabolism going on in the more fluid contents supplies the energy for living. But the gelled skeleton may participate in metabolic changes taking place in the fluids by which it is bathed. Through its adsorptive and enzyme functions it may not only act like a platinum sponge in effecting chemical changes in materials within it, but syntheses may be effected through which its own peculiar substance may grow. If through catalytic action different substances are built up in different parts of a cell, they may not diffuse uniformly throughout the mass for two reasons: (1) Complex molecules may be prevented from diffusion by the semipermeability of the surrounding gels, and (2) after their formation they may be united to the more or less gelled structure of the living tissue. They do not diffuse until they are uniformly distributed, simply because they are anchored as soon as formed.

In constructive chemical processes a very important role is played by the labile state of so-called living protoplasm, much of which

is close to the line between a gel and a sol. A fluid condition is eminently favorable for chemical action, while a more or less solid state is essential for the perservation of structural differentiation. Almost no chemical action goes on in a dried seed or a desiccated tardigrade, but when water soaks in and the tissues swell, numerous little chemical factories appear in the various cells and vacuoles of the organism, which is thus brought to life. Some organisms survive the almost complete absence of fluid, and others withstand the almost complete loss of solidified structures. The cytoplasm of some infusorians assumes a complexity and regularity of organization which rivals that of many multicellular animals. Nevertheless, in a number of species it is just *pro tem* construction. In these forms not only does a good deal of differentiation disappear during fission, but in the encystment stage it is almost completely resorbed and little else remains visible except the cyst wall, the nucleus, and the semifluid, almost homogeneous contents.

An intimate association of sol and gel affords a condition for the maintenance of different kinds of metabolic processes against the influences making for uniformity of chemical composition. Chemical differentiation occurs in spite of a seeming opposition of counteracting influences. The material basis for differentiation along diverging lines we may assume to be the possession of a variety of self-perpetuating genes, which by the kinds of enzyme action they exert are able to cause the different morphogenic changes involved in histogenesis. Each of these early cells has a varied repertoire, and the stimuli to which they are attuned to respond are furnished largely by their immediate environment.

The idea that differentiation rests largely upon gene action has been ably developed by Goldschmidt in his *Physiologische Theorie der Vererbung*. The genes are regarded as catalyzers (directly or indirectly) of various chemical processes, the products of the activities of one gene serving as the basis for the action of other genes which would otherwise lie latent. Through interactions between genes and cytoplasm a regular sequence of products would be formed in an epigenetic fashion based upon the preformed complex of the genes. With this basic feature of Goldschmidt's theory the views here set forth are, I believe, in entire accord. Other suggestive ideas in the volume referred to cannot be adequately discussed in the present connection.

Divergent differentiation we have looked upon as in the main the effect of morphogenic responses elicited through the equilibrating activities of the organism. Through the selection of gene mutations during the course of evolution we may suppose that embryonic cells have been endowed with their varied powers of producing morphoses on the physical and chemical level. Through enzyme action set up by genes we have a variety of proteins and other chemical substances which build up structures in the form of fibrils, lattices, and other elements commonly observed in different types of cells. Since many of the synthesized substances are capable of catalyzing other reactions in turn, and since the kinds of syntheses going on are influenced by other physical factors, we may have within the cell a variety of protein and other configurations produced in different parts. The part of a mesothelial cell adjoining a substratum often reacts by the formation of fibers, whereas the free surface may become thickened. The formation of fibers may take place in nonliving plasma in ways so closely similar to their formation within the cell that in many cases it is often difficult to decide upon their real place of origin. Polarity is often induced through the influence of contact stimuli, as is exemplified by epithelium in tissue cultures. These physicochemical morphoses are dependent upon genes and natural selection has chosen them on the basis of their ability to get along together. The way in which any aggregate develops, whether of genes or individuals in society, depends upon the selection of its members. The apparent goal-seeking which is often exhibited in such striking ways in ontogeny and other formative processes is not something primary. Ontogeny may be compared to a piece of music in which notes and chords follow in a very definite order from beginning to end.

The piece is learned only after many rehearsals in which all discords and false notes are thrown out. Or, to change the figure, we may say that Nature fills the nuclei of the germ cells with genes and then sees what kind of products result. The genes may produce a monstrosity, a weakling, or a highly successful organism. A point I would especially emphasize is that Nature has stocked the germ cells with genes which make for the interdependence of developing parts. She has made the parts in ways that aid in the development of other parts. If natural selection is capable of operating at all, there is no reason to doubt that it is quite within its competence to fit out the beginning individual with a collection of genes which would react to the organic environment by the formation of mutually dependent parts, each of which tends to grow on its own account, but whose undue growth or functioning would be checked through the reactions elicited from its associated organs. In this way an organism could become a self-regulating mechanism. It would have the capacity for making a number of direct adaptations, of correcting deviations from the normal, and of reacting in many ways that appear to be guided by the effort to achieve an end. Co-operation as a device for individual self-realization is a principle discovered in the course of evolution long before the advent of social groups. Parts of the organism become as much advantaged by it and dependent upon it as are babies in a human society.

Coming back to our question as to why the parts of a developing egg *tend* to diverge, one must say that there is no *primary* bent thereto, but that divergence is mainly a consequence of evocation, as in societies of human beings, and that it is closely tied up with the advantages of co-operation and division of labor. In other words, development is a kind of mutual evocatory process in which parts have been formed to react to certain organic situations, much as many animals are fitted with a number of specific instincts. From this viewpoint an organism in its development, regeneration, physiological functioning, and behavior is performing similarly in making responses to particular conditions, internal and external.

I have already called attention to the role of competition in the integration of life processes. This force may work destructively as well as constructively, but from the standpoint of the individual organism Nature has managed to keep it well employed by the way she has selected the genes. She has done this through the simple device of making competing parts interdependent. But along with this there has gone the development of checks to activity, especially exemplified by the formation of specific inhibitory substances which counteract the undue functioning of particular organs. Integration, which is achieved by an elaborate system of checks and balances, as in the social body, requires very different degrees of organization in different forms. Where there is a multitude of different kinds of genes, each endeavoring to have a finger in the pie at some period or other (else why should they be there?), the integration of all their activities could hardly occur other than in a complex organism.

The reasons for the repeated divergences of ontogeny are therefore to be sought largely in the complex of genes. The reasons for the seemingly teleological direction of formative processes are to be looked for in the same place. The germ plasm has been made thus and so through its phylogenic history, and it develops thus and so because its variations have been selected to react in a particular fashion. To the question why the organism mends its injuries, cures its ills, adjusts itself to new conditions, and exhibits so many adaptive responses to emergencies, or, in other words, behaves as if it were animated by a purposive striving after normal wholeness, the mechanists can only answer that it is able to do these things by virtue of its automatic functional balancing, which it owes to its genic construction. The apparently novel adjustments of the individual are after all a heritage of its past.

We are prone to look upon natural selection as working with finished products. Its chief concern, however, is with experiments in ontogeny. Organisms perish not only because they fail to respond properly to their environment, but because there is maladjustment in the internal machinery. A variant

internal stimulus may lead to death, or a stimulus may not be responded to in the proper manner. In either case there is lack of adjustment in the stimulus-response mechanism. Once sufficiently diverted from their usual course, formative processes may go on building ever further deviations and finally give rise to monstrosities, teratomas, and other anomalous products. All these realized ends of endeavor exhibit a marvelous amount of internal adaptation in their vascular supply, the disposition of their individual tissue, and in other ways that might well excite the admiration of a Paley for their adjustment of means to ends. We may call these products abnormal, but the abortive mouse embryos homozygous for dominant yellow are in one sense just as normal productions as their well-developed litter mates. The litter mates arrive at different goals, but each is a logical consequence of its complex of genes.

Despite many contentions to the contrary, ontogeny per se involves no striving toward a living or self-perpetuating goal. It may be quite as much a striving to produce an amorphous heap of cells as a viable organism. What it effects depends upon its outfit of genes. It owes the adaptiveness of its goal to its phylogenic history. Fitted out with a proper genome, it may attain its goal by varied and seemingly ingenious methods which may appear to necessitate an appeal to a vitalistic principle. There is nothing in the mere change from the simple to the complex that needs especially to excite our wonder. The striking feature for formative processes that has proved so puzzling is their resourcefulness in attaining their apparent goals amid circumstances which throw them off the usual track and lead them to adopt different methods of procedure to reach normal wholeness. But this seemingly end-seeking behavior has its ground in the forces that have guided the selective preservation of mutant genes.

(To be concluded)

THINGS ETERNAL

What seems more stable than some mighty mountain range?
And what more frail than wing of butterfly?
Yet mountain ranges rise and wear away
Through eon after eon of unending change.

While patterns of the insect wing, unchanging
In the species, though each butterfly must die,
Persist through countless generations,
Outlasting, in the end, the very granite hills.

Such constancy, in fragile organism—
Its physiology in equilibrium
With all the forces of environment,
Through geologic time—is worth our awe
Like constellation spangled skies at night,
Or like the Andes rising from Pampean plain.

—KARL P. SCHMIDT

SCIENCE IN FRENCH CANADA*

II. SCIENTIFIC ENDEAVOR

By PIERRE DANSEREAU

It is hardly possible in a few pages to trace the whole history of science in French Canada In the first place, such a history has never been written. At best only an outline can be given of the evolution of scientific thought and methods, and a brief description supplied of original achievements and contributions.

Preinstitutional period. Among the French colonists who came to this country before 1763, many were well-educated men, as Peter Kalm remarked,[3] and with a frame of mind which led them to speculate on what they saw, and in some cases to express their observations in their reports, diaries or *relations,* sometimes in surprisingly incisive form. The great discoverers themselves, Cartier and Champlain, for instance, have given us accounts of their experiences which are considered valuable by science today.[4,5] Men like Louis Hébert[6] and Michel Sarrazin[7] were scientists in the exact sense of the term. The latter kept up a correspondence with Tournefort at the *Jardin du Roy* in Paris. In his honor that extraordinary North American freak, the pitcher-plant, was named *Sarracenia purpurea.*[8] Many interesting observations are also to be found in Pierre Boucher de Boucherville's book (1664) entitled *Histoire véritable et naturelle de la Nouvelle-France.* Also, Charlevoix, Sagard, the Jesuits, and other historians and chroniclers have given us fragments of the natural history of our country.

But all this does not amount to a true scientific movement, does not create an atmosphere, even less a tradition. In fact, the early part of the nineteenth century was quite unproductive. It was not until the 1860's that notable scientific activity was initiated. In 1868 *le Naturaliste Canadien,* a periodical still in existence, was first issued by Abbé Léon Provancher, who also published an entomological fauna[9] and the first flora[10] of Canada.

Abbé Provancher, Abbé Brunet, Monseignor Laflamme, and others were pioneers in Canadian science. Today their modest essays do not appear very important; no doubt their greatest contribution was to create an atmosphere favorable to the founding of scientific institutions of lasting value. In an overwhelmingly scholastic milieu, theirs was a difficult task to induce the proper and indispensable respect for science.

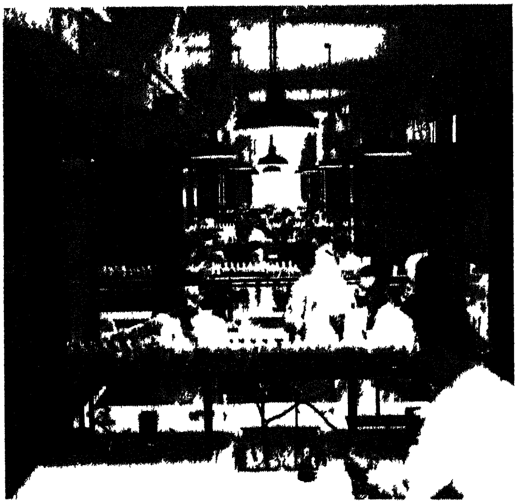
Institutions. A nation's cultural activities may be best reflected by the character of its institutions, although that is not the only criterion. Surely universities and schools of higher learning are at once the depositories and the authorized interpreters of that nation's most valued intellectual traditions. So it is in French Canada, where, from the first, the seminaries took the lead and gave rise to the universities, which, in turn, promoted other institutions.

The *Séminaire de Québec* was founded in 1663 and became in part Université Laval in 1852. Its history is not without analogy with that of some of the more illustrious American institutions, such as Harvard University (Harvard College from 1636 until 1780). The *Ecole de Médecine* in Montreal (later the Faculty of Medicine of the *Université de Montréal*) was founded in 1843. The *Université d'Ottawa* was founded in 1848 and that of Saint-Joseph, New-Brunswick, in 1864. *Université de Montréal* originated in 1878. The professional schools of engineering (1873), agronomy (1893), commerce (1907), forestry (1907), and mining (1938) were opened later and duly affiliated with either the *Université Laval* or the *Univesité de Montréal.*

Today, these institutions are flourishing and have many thousands of students. *Université de Montréal* has 950 professors and

* Continued from p. 194 of the preceding issue.

[3] Superscript numbers refer to "Literature Cited" at the end of this article.



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CHEMICAL LABORATORY, MONTRÉAL

over 7000 students (50 and 413 in the *Faculté des Sciences*); *Université Laval* has 355 professors and about 2000 students (86 professors and 302 students in science, and 71 and 117 in the Graduate Faculty). As for *Université d'Ottawa* (with 187 professors and 2000 students) and *Université Saint-Joseph* (with 45 professors and 430 students), they are not universities in the full sense, but colleges.

It may not be unnecessary to remark at this point that all courses in these universities are given in French. Their role in keeping French culture alive in Canada is outstanding, for the French Canadian's language is a very living thing. It differs only slightly, if at all, from the language spoken in France; not quite as much, perhaps, as American does from English. The French Canadian's language may be a little provincial and archaic; it is, however, no mere sentimental symbol of past allegiance, but a living instrument for the expression of all phases of his personality.

The relative isolation entailed by it has more than once put him to a disadvantage, notably in the realm of science. His is a constant problem of adaptation. The nineteenth century has been very difficult, because it did not appear any too clearly that he could manage to put up the institutions of higher learning indispensable to the survival of a culture he cherished. If French Canada's individuality was safeguarded a first time in the early nineteenth century by aloofness, it could not be saved again by that means in this mechanical age.

The game, however, has been played and won, or so it seems today. Montreal and Quebec have universities of good standing which can prepare men to stand on both feet on the international scene. The native intelligence and resources of the French-Canadian can now be developed to the full in his own country. The battle of tomorrow, so far as he is concerned, is no longer direct physical, economic, or cultural adaptation to this North American environment. The next test in the struggle for survival of French Canada—as of most small nations no doubt—will be the faculty to produce men of outstanding ability, capable of influencing to some degree international thought; political, artistic, scientific, or all three.

Just how well equipped is this group of four million North Americans to put forth creations capable of influencing somewhat the course of humanity's progress? This would seem a grandiose way of putting it to some French-Canadians, for not many have such lofty ambitions. It may be that all too few realize that the problem really lies there, and no doubt the period immediately following this war will appear to justify the minders-of-their-own-business and other pessimists.

But if French Canada is not just a little ahead, intellectually, of some of its more powerful allies, it runs a very real danger of sinking into insignificance. There is reason to hope, however, that its heritage has prepared it for the rather tremendous intellectual effort which will give it some measure of leadership. Switzerland, Sweden, Denmark have done something of that sort in Europe in the first half of this century.

Surely for the sociologist, the ethnographer, the anthropologist, it is well worth while to look into the destiny of this small people. Their history presents a clear-cut pattern. Their intentions are quite simple too. A precise ecological study of their adaptation to the ruddy Laurentian landscape would well repay the investigator's effort.[11] The incipient stages of a new French culture should matter to America. Whether there be any future in it can best

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LARGE LECTURE HALL, MONTRÉAL

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ANOTHER VIEW OF THE SAME HALL

be judged by the quality of that culture, by its trueness to the fundamentals of civilization itself. And that is to be measured not by numbers, but by spirit.

The philosophical trend. Even more significant, therefore, than the above-described institutions is the spirit behind their evolution, outwardly so similar to American and Anglo-Canadian institutions.

It may appear at first that the total number of postgraduate students is small. Here is the very judicious explanation by an Anglo-Canadian professor of physics[12] on the subject:

The insistence in these universities on (i) a broad training in the humanities before specialization in science, (ii) the thorough mastery of two or more languages and, (iii) special attention to subjects considered to be of value in cultural development and character formation, is in part responsible for the postponement of advanced work in physics by their students to periods of graduate training at other universities.

The quality of the general education and the distributed culture of the better French students, which arises from this policy, often puts to shame their English-speaking friends of similar age. The latter have frequently confined their attention too soon and too exclusively to specific subjects or to specific professional training. It would appear that Canadian physicists in general have too often neglected important ingredients in education, and should possibly take steps to defer the specialization of a student until a proper standard of general education has been attained. On the other hand, it must be realized that university standards in physics cannot be obtained without an exceptionally intense training, in an atmosphere in which the active advance of knowledge exerts an unceasing influence. Adequate mastery of mathematics and the methods of scientific thought and procedure are rarely ever obtained by a student who has devoted the golden years of his teens more to the cultivation of memory than of reason, and more to following than to exploring and applying.

This last paragraph emphasizes the delicate balance which an ideal system of education should seek between information, specialization, and actual knowledge of separate and demonstrable facts on the one hand, and culture and the power to reason, on the other. No doubt our French-Canadian system will appear to many to stress synthesis with too few facts, too little analysis; while to others it will seem that the current American and Anglo-Canadian system affords too little correlation between otherwise well apprehended facts. This problem is foremost in the minds of many teachers. It would seem that several American educators feel rather strongly on this point and urge a reaction against the excesses of vocational training in the universities. Among others, the president of the University of Chicago has quite forcibly expressed this point of view: it seems to him that premature specialization is responsible for the narrowly limited intellectual horizon of many otherwise intelligent and progressive Americans.[13]

I also had occasion only recently to hear several discussions in Middle Western institutions of the "liberal arts" and their place in education. It was often agreed that the student's capacity for earning a living far outran his participation in that accumulated "wealth of nations" past and present, known as culture.[14] A new type of school has recently originated at Annapolis, Maryland, in response to this feeling. Specialization is

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resolutely abandoned, direct access to the classics is stressed.[15] The St. John's experiment is not without analogy with the French-Canadian *cours classique*.

On the other hand, French Canadians are well aware—because they have paid the price—of the inconveniences of a too speculative education. This has been the main cause of their failure to control their own commerce and industry and of their relative backwardness in creative science. However, they are generally agreed that the "classical" system may be in need of modification but it must not be abandoned. In the words of the present Minister of Education of the Province of Quebec, the Honorable Hector Perrier, addressing the *Canada and Newfoundland Education Association* and referring to Quebec's differences with the other provinces: "We must seek the solution of our educational problems not in uniformity of programmes and systems, but in an open-minded collaboration and a healthy emulation with the other provinces."

The basis of French-Canadian education therefore remains unchanged; it is humanistic and can only become more so by an intelligent and more comprehensive integration and diffusion of contemporary science. It can very well be argued, in fact, that a humanistic background provides the best setting for scientific work. Only recently Whittaker[16] pointed out that "of all types of philosophy, the Aristotelian-Scholastic is, in its principles, the most congenial to the scientific mind." To the French-Canadian educator, scientific facts and theories have little pedagogic value until they can be so integrated. Surely this attitude is intellectually no more dangerous than its opposite, which consists in a purely utilitarian conception of science. Economically and socially, of course, it can be disadvantageous. French Canadians do not fail to see this point. But they apparently care more for their traditions and way of life than for economic advancement.

It is no doubt well, and assuredly logical, that scientific progress in French Canada has not taken place too suddenly. It could then scarcely have failed to have been imitative to a degree hardly compatible with authentic personal expression. There is no need to discuss here the principle of French-Canadian culture as a whole, of its distinctness and relative isolation. It may be that Canadians would be better off if they all spoke the same language and all that. But the fact is that they do not, and apparently they have every intention of maintaining the *status quo* in cultural matters at least. Let us take this for granted and proceed to appreciate the modalities of this culture as it stands.

Educational practice. The educational pattern of French Canada is very much as follows: After about six or seven years of primary school, a child is sent either to the classical college or to a primary superior school. The latter offers six or seven years of study which do not lead to a bachelor of arts degree but allow entry (usually following a special examination) to some of the Faculties. The classical college has four years of "high school" and four years of "university course": *belles-lettres* (freshman), *rhétorique* (sophomore), *philosophie I* (junior) and *philosophie II* (senior). The university then grants the degree of Bachelor of Arts (B.A.). These studies are not exactly equivalent to either high school or college of the American system, as will be obvious from further description of the curriculum.

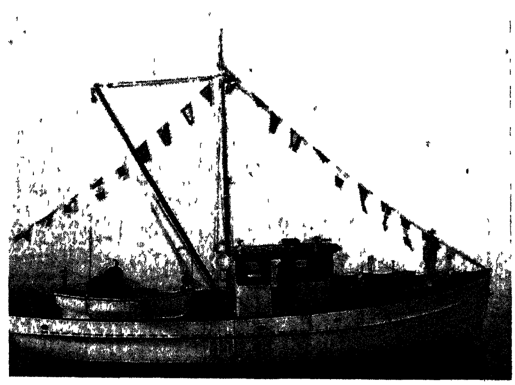
The *cours classique* is not carried on in the university proper but is conducted in twenty-three classical colleges affiliated with the *Université de Montréal* and almost as many with *Université Laval* of Québec. The directors of these colleges, together with rep-

resentatives of the University, constitute a Faculty of Arts—extramural, so to speak. It is this body which legislates on the programs to be carried out, more or less uniformly, in the colleges. Each college maintains some measure of autonomy. I can see no cause for alarm on this score since it is likely to, and in fact does, stimulate emulation, and also since it makes for diversity and the establishment of separate standards of excellence.

The *cours classique* does not afford options of any kind. The general curriculum, comprising both literary and scientific subjects, is followed by all. It has been pointed out above that the science program of these institutions, until quite recently, left much to be desired. In many of them nowadays a satisfactory balance is being reached between the two major interests. No specialized training, or very little, is offered because it is generally felt that before the student can accurately and wisely choose, he must have learned enough of each subject to understand its significance and to test his own aptitudes. It is unthinkable to educators in French Canada that any student be allowed to "skip" any subject altogether.

The student then comes to the university or to one of its affiliated professional schools. He can study: theology (Catholic), law, medicine, philosophy, letters, science, dentistry, pharmacy, social sciences, which are represented by as many faculties; or engineering, agriculture, veterinary medicine, commerce, optometry, forestry, mining, electricity, taught in affiliated faculties.

Now to consider the Faculty of Sciences which concerns us more immediately: To anyone familiar with the system of education existing in France, it is obvious that the scheme outlined above closely resembles it. The curriculum, although somewhat influenced by Anglo-American institutions, has a basically French structure. The unit is the *certificat*; that is, a homogeneous series of lectures and laboratory periods covering a period of one year and involving several instructors. For instance, a *certificat* of Comparative Morphology of Plants comprises: Comparative Morphology of Fungi (30 hours), of Algae and Bryophytes (30 hours), of Vascular Plants (30 hours),



Dr. Jean-Louis Tremblay, Quebec

YACHT OF THE FACULTY OF SCIENCES

USED IN THE GULF OF SAINT LAWRENCE FOR PREWAR OCEANOGRAPHIC AND BIOLOGICAL INVESTIGATIONS.

Phanerogamy (30 hours), Geobotany (20 hours), Phytopathology (10 hours), Economic Botany (30 hours), and an equivalent number of laboratory periods.

With three such certificates in any one, two, or three branches of science (Mathematics, Physics, Chemistry, Biology, Botany, Geology) to his credit, the candidate receives the *license* (L.Sc.), which is equivalent to the American B.S. with honors. Practically, the license proves most valuable to teachers in primary and secondary schools and large numbers obtain it in the years following their graduation from normal school.

Also, it is considered a necessary step to either the Master's degree (M.Sc.) or the doctorate (D.Sc. or Ph.D.). As concerns these degrees, there is little to say: the formalities, studies, and research involved are very much the same as in any other North American university, or any European institution, for that matter.

Professional organization. Scientific societies have existed in French Canada for over a century, some of them devoted to pure science, others to the advancement of professional standards.

Today forty-five of these societies are affiliated with the *Association Canadienne Française pour l'Avancement des Sciences* (ACFAS). This federation, built on the model of similar organizations of longer standing in other countries, was founded in 1923. Its period of greater efficiency, however, was initiated in 1933 with the first an-

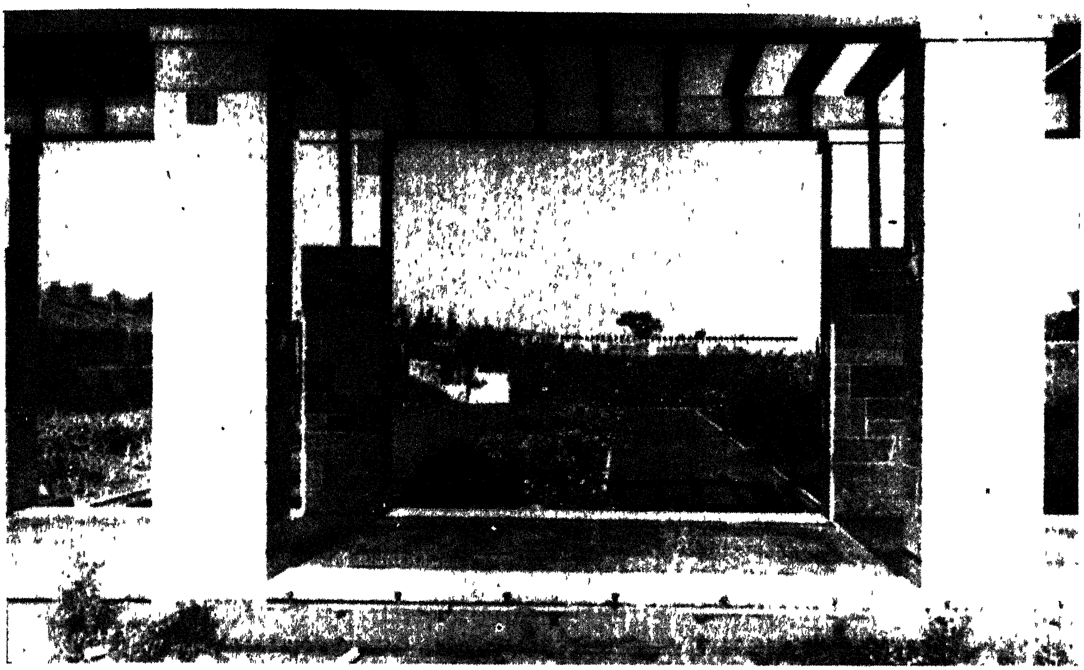
nual convention, held in Montreal. The impetus given to research since then has been truly remarkable. Many scientists, especially those not inhabiting the larger centers, were greatly encouraged and stimulated by yearly contact with fellow workers. This especially applies to technicians employed by various state departments (Agriculture, Forestry, Mines, etc.). The role played by the ACFAS is somewhat similar to that of the various American State Academies of Sciences. Such institutions provide a platform for scientific workers; an occasion for exchange of ideas and for discussion. They also stimulate research and publication. I believe that the output of French-Canadian research could be shown graphically to have marked a decided and unfailing upward trend since 1933.

Many of the scientific societies involved, however, had reached extensive development even before then. Such is the case of the *Société Canadienne d'Histoire Naturelle*, founded in 1923 and open to amateur as well as professional naturalists. The greatest achievement of this society is its sponsoring of the *Cercles des Jeunes Naturalistes*. The junior naturalists club aims to "train its members in the study, observation and sympathetic comprehension of Nature in all its aspects."[17] The first one was founded in 1931 by Brother Adrien, C.S.C., and in 1943 there were over 900 clubs with more than 28,000 members. Branches had been established in the other provinces of the Dominion and in other parts of the world where French is spoken: in France, in the United States, in Egypt, in India.

The history of that movement is a most engrossing one[18] and it is very important to the scientific development of the last twenty years in French Canada. The dominating figure has been Brother Marie-Victorin, the great botanist whose influence has extended beyond his chosen field and even beyond that of the natural sciences. Many of the most promising young scientists of today in our universities received the revelation of their vocation and their first training in one of these junior naturalists' clubs. Today there is a rather sharp distinction between two generations in respect to early-acquired knowledge of the natural environment.

No less important was the foundation, approximately at the same time in Montreal and Quebec, of distinct Science Faculties. In Quebec Monseignor Alexandre Vachon—a distinguished chemist, now Archbishop of Ottawa—with the dynamic collaboration of Mr. Adrien Pouliot, engineer and mathematician, created an *Ecole Supérieure de Chimie*, which was enlarged into the *Faculté*

ADMINISTRATION BUILDING, MONTREAL BOTANICAL GARDEN
CREATED IN 1936, THE GARDEN IS MOST MODERN AND WILL BECOME ONE OF THE LARGEST IN THE WORLD.



PART OF THE PERENNIAL GARDEN, MONTREAL BOTANICAL GARDEN

des Sciences de l'Université Laval. In Montreal it was also a chemist, Dr. Georges Baril, who was the soul of a young but progressive Faculty of Sciences. Economic pressure and the need for specialists in many fields not covered by the already existing professions were potent factors in the promotion of these independent science faculties. The men of vision who created them have amply proven their usefulness.[19] They have done more than that; they have given the pure sciences a status which they did not officially possess till then.[20] It can be said that independent research only then became possible. Today, the various departments of these two faculties of sciences at Montreal and Quebec are well organized in new buildings and have laboratories adequate for practically all phases of research. Even more important, their staff comprises an increasingly large number of young scientists trained in the American and European universities. Some of them already have attracted some measure of attention by their publications.

Much could be said of scientific societies—medical, legal, agricultural, chemical, and otherwise. Some have a fairly long standing and have rendered many a service. But I cannot do them all justice here. Let me mention, however, the Royal Society of Canada, which has elected many French-Canadian members. This national academy has done much, together with the National Research Council, to encourage and to promote research.

Technical adaptation. In the fields of agriculture, silviculture, mining, and the exploitation of natural resources generally, we have fine examples of the French Canadian's adaptation to his North American background. Many colonists, from the beginnings of the French regime, felt very keenly the tremendous possibilities of this new country and early abandoned all ideas of modeling it on the agriculture and general economy of the mother country. This led to many conflicts, the most notorious being that of General Montcalm and Governor Vaudreuil.[21] People like Maisonneuve, the founder of Montreal, Jeanne Mance, Jean Talon, Pierre Boucher de Boucherville were authentic Canadians and constantly sought for adaptation and not imitation.

At the beginning of the British regime, the farmers of Lower Canada had already created a hardy and efficient race of general-

purpose horses. They had also bred a strain of cows for their excessive frugality and hardiness. Both these breeds are now recognized in international exhibitions and have closed stud books. A system of agricultural economy gradually became established which was both rational and efficient. It implied few scientific principles, if any, but allowed the *habitants* of the old parishes bordering the Saint Lawrence to make a living—indeed in many cases to become well-to-do.

But presently the need was felt for improvement, and this time French Canada did not look to France, but to the United States to help it solve its problems. Young silviculturists and agronomists, trained as well as they could be in our schools, were sent to Cornell, Harvard, Yale, Iowa State, Massachusetts State, Michigan. They were usually gifted students, quite capable in spite of the shortcomings of their basic training of following advanced courses. Also, they managed, upon their return, to adapt their knowledge to the conditions of Quebec; edaphic, climatic, cultural, economic.

The job they have done is by no means perfect. It was not always understood by the public and by the government that it was worth while to spend a lot of money on scientific training and research. Because of this lack of appreciation, our agronomists and silviculturists did not manage to impose the high scientific standards of which they had dreamed. They were forced by circumstances to be, above all, practical men. Many of them never rose above that level. But all realize today the need for the technician of a broader scientific outlook.

The damage done by man in depleting the natural resources of Canada is no doubt considerable. The lack of proper management leaves us today facing unforeseen problems. These, however, may not be as great as those of many American States where man's remodeling of the landscape has created a state of unbalance nowhere nearly as beneficial as had been hoped.[22]

This whole subject of the technical adaptation of the French Canadians to their landscape and of the scientific principles invoked by them—even implicitly—calls for the preparation of an extensive book. Everett Hughes, of the University of Chicago, has given us a valuable contribution in that sense.[11] We can hardly draw the whole picture here, important as it is to our subject, but we can at least try to delimit which factors are scientific and which social and political.

Let us look, in that light, at the forests, the land, the fisheries.

The forests of the Laurentides have been cut abusively in districts generally unsuited to agriculture and opened under the guidance of well-intentioned but poorly-documented missionaries. Those of the Northland have been mostly ceded to capitalists of diverse (non-French-Canadian) origins, in whom it is not surprising to discern no thought for the future. That French-Canadian governments at Quebec have allowed this to happen is due only in part to diverse forms of political and economic pressure. The general feeling of the inexhaustibility of our woodlands is only now beginning to wear off. The very wise silvicultural policy of the Swiss, French, and Scandinavians has only recently appeared urgent here.

As for the land, it has long been managed under the system of private ownership by routine unimproving methods. Regional specializations, like dairying, are by no means new, however, and many of them can be said to have been successful for a number of years; for example, the cultivation of tobacco in the Joliette area, of vegetables on Isle d'Orléans and Isle Jésus, of flax in Charlevoix, of peas in Gaspé. But what a tremendous need there still is for experimentation! Very few new varieties have been created for the particular conditions occurring in Lake Saint-Jean, in Gaspé, in Abitibi, or even, for that matter, in Quebec or Rivière-du-Loup. The Montreal plain has produced the famous Montreal melon[23] and the Oka melon, but not a single variety of tomatoes, lettuce, celery, potatoes, and other truck crops. American and Ontarian varieties have been tested and to a certain extent bred locally, but there has hardly been a general breeding program to suit the specific needs of the province of Quebec.

I feel bound, however, not to pass over silently the work done at the Central Experimental Farm at Ottawa and at Macdonald

College, P.Q. That French Canadians have played a decidedly minor role in both these institutions can be accounted for in many ways, not all of which are to our advantage—and none of which, I am afraid, will show national unity in a very favorable light. However that may be, it is not surprising that much of the work at Ottawa was concentrated on the needs of the predominantly agricultural and highly productive western provinces, and at Macdonald College mostly on the benefit of the English part of the province of Quebec, once conceded to the United Empire Loyalists, the Eastern Townships.

No picture of agriculture in French Canada is complete without an outline of the work of the technical agriculturists, the *agronomes*. These men, trained in one of our three agricultural schools (*Institut Agricole d'Oka, Macdonald College, and Ecole Supérieure d'Agriculture de Sainte-Anne-de-la-Pocatière*) and awarded a B.S.A., now constitute a recognized closed corporation, equal in standing to that of the lawyers, pharmacists, physicians, and engineers. Most of its members are employed by the state. They are mainly responsible for the many intelligent applications of agricultural science to local needs: for the devising of drainage systems, the introduction of new cultures and of fertilizers, the diffusion of pure-bred stock, and so on. Some of these men have been pioneers in more ways than one and deserve much credit. Their role in bringing science to the people can hardly be overestimated; today every farmer knows the meaning of protein, vitamins, and pure-bred lines because he has been made conscious that such things were not out of a textbook but living things in his own back yard.

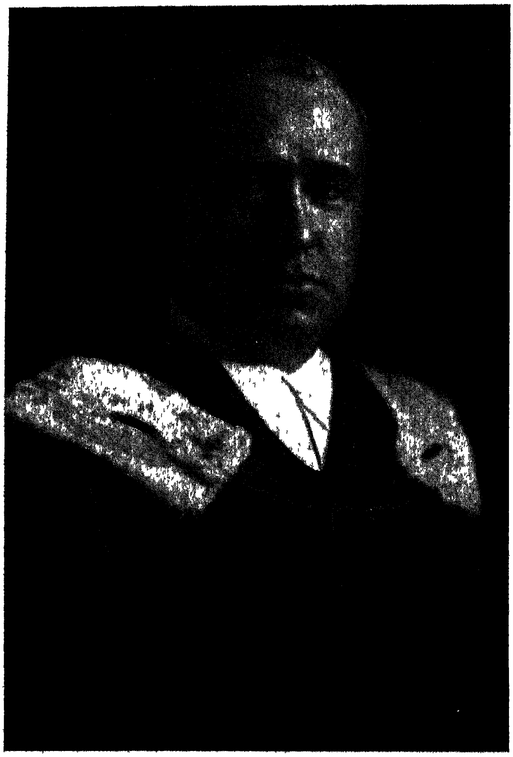
As for the immense wealth represented by the fisheries of French Canada, that is in some ways a moot subject. The impact of science on the fisheries of the Gulf of Saint Lawrence has been felt none too keenly in the past by the French-Canadian fisherman. He has recently been freed by the co-operative movement from an age-old, quasi-feudal servitude imposed upon an ignorant and poor population by wealthy foreign companies eager to keep cheap labor cheap. This situation, now nearly at an end, may have been to the detriment of the local human population but was not noticeably so to that of the fisheries themselves. In fact these same companies were always eager to adopt new methods, especially of preservation.

The case of salmon fishing and the general relationship of sport and commercial fishing also involve political and economic factors present elsewhere and, I think, to more or less the same degree. If the sportsman's intentions are not to be questioned, surely there is as much need for him as for the commercial fisherman to call for the advice of the biologist, especially the ecologist. Much unwise legislation, in all parts of the world, is due to lack of biological knowledge or to ignorance of such as is already available. On the whole, in Quebec the protection of our biological resources is in many ways ahead of that in other parts of this continent. Our legislation has usually been based on sound, if summary, information and has proved fairly efficient.

Original contributions. It is fitting, in concluding this review of science in French Canada, to give a little detail about the achievements of some of the men of science who have been bred and have worked in the atmosphere described above. Very few of them have gained international renown. All of them have considerable merit and deserve to be better known outside our frontiers. All have one thing in common, and that is the pioneer spirit. They are men who have felt very keenly the stimulus of new problems and they are the more typical French-Canadian in that their work can be seen to have responded to the requirements of their cultural and geographic environment.

And perhaps first of all, I should name Captain Bernier, the grand old skipper of the *Arctic*, an exploring vessel dedicated to the discovery of new lands in the frozen North and to the investigation of their resources. Many useful data—geographic, geological, botanical, and zoological—have resulted from his famous trips. He was born at l'Islet, on the magnificent Saint Lawrence below Quebec and died at Lévis in 1934 at the age of eighty-one.

Pierre Fortin, the initiator of fisheries research in Canada in 1852, was another sea-minded Canadian. He was a man of con-



Dupras & Colas, Montreal
BROTHER MARIE-VICTORIN, 1885–1944
LATE DIRECTOR, BOTANY DEPARTMENT, UNIVERSITÉ DE MONTRÉAL AND OF THE MONTREAL BOTANICAL GARDEN.

siderable intellectual curiosity and also a man of ability and endurance, for he was sometime physician, member of Parliament, magistrate, and scientist. "He described the fishes (naming a few species) as well as the fisheries, and developed a system of detailed fishery statistics that was adopted for the rest of Canada and that has given this country these basic data for fishery research, collected in more detail and continuously for a longer period than holds for any other country."[24]

In more recent years investigations of our marine biological resources have been very much to the fore. The present Archbishop of Ottawa, Monseignor Vachon, who was then dean of the Faculty of Sciences at *Université Laval*, organized the *Station Biologique du Saint-Laurent*. There were carried on systematic explorations of the marine fauna of the Gulf of Saint Lawrence, studies of the life-habits of such important species as the herring, the cod, the lobster.

Professor Georges Préfontaine, head of the *Institut de Biologie* at the *Université de Montréal*, co-operated with the *Station Biologique du Saint-Laurent* from the first on many of these projects. But his life's work has been the study of the Atlantic salmon, on which he has published several papers and is still active. Dr. Préfontaine was also born in the open reaches of the Lower Saint Lawrence, at Isle-Verte, and that may be a significant fact. He, like Pierre Fortin, first got his M.D. degree. Then he received a Rockefeller scholarship and studied several years in France, mostly at Strasbourg and Roscoff. He has exerted considerable influence in the shaping of French-Canadian scientific organizations, especially on the teaching of biology and the initiation of research at the *Université de Montréal*.

The history of botany in French Canada is rather longer and more eventful than that of the other sciences.[25] Its modern phase started with Provancher and Brunet (mentioned on page 261). However, it was seemingly interrupted until almost the beginning of World War I.[26] It was then that a modest brother of the Christian Schools became known to a number of correspondents in France, England, South Africa, the United States, and elsewhere: Brother Marie-Victorin, who died on July 15, 1944, at the age of fifty-nine.

It will prove difficult in a few paragraphs to summarize the accomplishments of Marie-Victorin and to define his influence. In the first place comes the personal, creative part of his work. He had no less than eighty-five scientific publications to his credit, not counting literary and popular writings.[27] His best known work is no doubt the monumental *Flore Laurentienne*,[28] a masterly piece of work, containing not only a description and illustration of the species of plants growing in the Saint Lawrence Valley, but a wealth of footnotes, most of them resulting from personal observation and deduction. The accurateness and richness of this work is paralleled only by its usefulness to botanists, agronomists, silviculturists, and others in all of eastern North America.[29]

Therefore, Victorin was not only a florist in the old-fashioned sense but one of the most significant phytogeographers of his genera-

tion. Though he repeatedly acknowledged the influence of Professor Fernald of Harvard,[30] his point of view was original and inspired by a vast traveling and reading experience. His contributions to the geobotany of North America[31] will stand as landmarks in the development of that science. More recently, he turned to tropical botany and published several contributions to the flora of Cuba.[32]

But that was not his whole work. He created two large institutions: the *Institut Botanique,* which is the Department of Botany of the *Université de Montréal*[10] and the Montreal Botanical Garden. The latter, although it was created only in 1936 and although its development was partly arrested by the war, is one of the finest and best-organized institutions of its kind in the world.[33] In scientific circles, Marie-Victorin's influence can hardly be overestimated. He was the dominating figure in the junior naturalists' clubs, which he inspired and guided for years, as also in the *Association Canadienne-Française pour l'Avancement des Sciences* (ACFAS), of which he was one of the charter members. He determined and helped to forward many a scientific vocation in practically all fields of science.

One of his lifelong friends was Dr. Léo Pariseau, a man of very heterodox ideas. Pariseau, who passed away in January, 1944, was one of the finest personalities ever produced by French Canada. On the surface, he had much of Voltaire, being a nonconformist and extremely intolerant of all forms of stupidity, dishonesty, hypocrisy, and even foolishness. But he had even more of Don Quixote and Galahad, for all his life has been a crusade. It is no wonder that such a man often found himself at odds with the educationally ruling class, the clergy. As a matter of fact, he has sometimes been taxed with anticlericalism. But among all the clergy there are no doubt very few as godly men as he. The very reverence he professed for truth and for honesty proved unbearable to the more reactionary and self-satisfied members of an unthinking society.

Pariseau was a distinguished physicist and has published many papers on electrophysics and electrotherapy.[34] He was a living encyclopedia and had assembled, in a

Dupras & Colas, Montreal

DR. LÉO PARISEAU, 1883–1944

A PHYSICIAN AND PHYSICIST, HE WAS ONE OF THE MOST BRILLIANT PERSONALITIES OF FRENCH CANADA.

lifetime, a collection of ancient scientific books, unique in America, which he had recently donated to the *Université de Montréal.*[35] Most of all, however, he has kept burning the torch of independent thinking. He has fought all forms of dogmatism, all brands of scientific heresy and charlatanry. He has few direct pupils, but most French-Canadian scientists owe to him much of their awareness of scientific issues and of the relative peace which now protects honest research.

There are quite a few others whose merits would entitle them to be named here. Among them are many professors who came from France and to whom Canada owes a great debt. But let the brief outline of these few personalities serve as a cross section through the French-Canadian scientific milieu. Today there are a large number of men, mostly between thirty and forty, whose work may turn out to be important tomorrow. In the postwar world let us hope for new opportunities in research. Many young French

Canadians have received a broad training in Europe or in the United States and are even now prepared to embark upon the study of significant problems. They all feel that what they have borrowed from other nations they are now bound to return in the form of original contributions to the science they are serving.

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EVOLUTION OF THE WHEEL

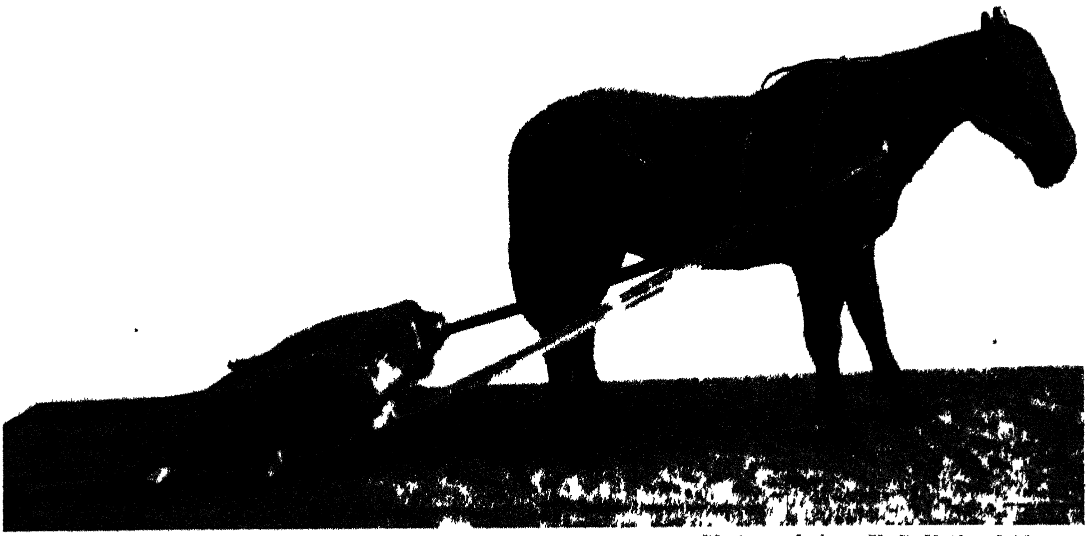
By H. E. KLEINSCHMIDT

HISTORIANS who trace the evolution of man from naked savage to civilized being seldom fail to mention that the wheel is one of the five or six devices that made his progress possible. In what way the wheel served to advance him out of his animal state, and how the wheel was invented, is left unsaid, except for general comments about rollers and runners. This unsatisfactory explanation of how the roller became a wheel or the runner a chassis is not the fault of the historian, exasperating as it may be to the reader, because the wheel was developed long before history was recorded and because the remains of primitive man's handiwork are too scanty to reconstruct the steps in the discovery of the wheel principle.

It is easy to test the absolute dependence of modern man's existence upon the wheel. The sugar he pours on his breakfast cereal was delivered to him on a wheeled truck and, before that, rode in a wheeled freight car. The cane from which it was extracted was hauled in a crude cart, then perhaps, on a "dinky" railroad to the mill where it was ground up by a bewildering contrivance of wheels and rollers. Similarly, his milk, bread, bacon, and coffee came to his table by means of wheels. Donning his hat and coat, manufactured and delivered to him with the aid of wheels, he rushes to the bus or street car and he depends upon the elevator to hoist him safely to his office. There he sets in motion various kinds of office machines, all of which include wheels in their construction, as he supervises a factory, a railroad, or a sales campaign requiring travel and transportation. Sudden stoppage of all wheels would mean death for our way of living; if not sudden, none the less sure. Transportation and machinery make our present manner of life possible. The ultimate unit of land transportation and the essential unit of machinery is the wheel. Peacetime intercourse as well as modern warfare are inconceivable without the wheel. One is tempted to say sweepingly that without the wheel civilization would have been impossible.

And yet, who knows? At least it is interesting to speculate whether or not, if this ingenious mechanical device had not been discovered, man would nevertheless have found a way of solving his transportation problems. After all, the wheel is but a means of reducing friction to a minimum so that loads may be drawn over a surface from place to place. Without the wheel man might have exercised his ingenuity in overcoming friction in other ways. Modern physics and chemistry suggest that the easy gliding of one body over another may be feasible. For example, electric currents can be made to repel objects as well as to attract them, and the chemistry of lubricants is just beginning to be understood. If there were no wheels, it is possible that science would find a way of utilizing other methods for transportation. Furthermore, air transportation promises to supersede much of our present laborious land transportation. If it be argued that the airplane propeller (or the ship's propeller, for that matter) is a wheel, it may be countered that the propeller is in reality a screw and not in any sense a wheel. The mechanical principles of the propeller and of the load-bearing wheel are widely different. Substitutes for the wheel used for the transmission of power might also have been found if this handy device had not been available. Pulleys, gears, and fly-wheels are indispensable in our present machinery, but who will contend that, if absolutely necessary, wheel-less machinery could not be devised to do the work now accomplished by wheels. At any rate, the wheel is here, serving us constantly and efficiently, and its history reaches back into the dark gropings of primitive man.

Strangely, there are no wheels in nature, although most of man's essential inventions have apparently been suggested by natural phenomena. Primitive man, for example, found a variety of uses for the forked stick, and to it we may trace such varied contrivances as the plow, the table fork, and probably the hammer and the pillar for roof support. A duck paddling in the pond is a



Photograph from U. S. National Museum

INDIAN TRAVOIS

"natural" boat, and soaring birds undoubtedly put the idea of flying into the mind of man. Eli Whitney solved the problem of ginning cotton by observing a fox clawing through the bars of a chicken coop in a vain effort to capture a hen. The animal's claws brought away feathers but left the hen otherwise unharmed, and Whitney caught the idea of mechanical claws working through a restricting grating which would pull cotton fibers from the boll and leave the seeds behind. But no such help from nature was afforded man in his quest for a wheel. Although locomotion is a distinguishing characteristic of animal life, and although fins, wings, and legs are abundantly bestowed upon living creatures, nothing in nature is known to move about on wheels nor to use wheels in any manner whatsoever, physiologically. There are a few so-called "pulley muscles" which turn corners, but the pulleys are nothing more than spicules of bone. Oliver Wendell Holmes, in a sparkling essay on "Walking," was led into the error of assuming that human locomotion is a wheel-like action. Each leg, he pointed out, is a spoke hinged at the knee, the upper end of which pivots at the hip while the feet are but sections of the rim. But the important functional difference between legs and wheel is this: walking is a reciprocal motion, whereas the wheel moves in a continuous direction. Reciprocal motion is wasteful; power is consumed to start and to stop motion, whereas the continuous revolution of the wheel benefits by momentum. Even if Holmes had proved his point that legs are wheels in principle, by no stretch of the imagination would walking ever suggest wheel construction to the mind of man. The wheel is a purely man-conceived invention, created out of the void of his own mind. Doubtless God can make a wheel, but evidently He never did.

The Disc Wheel

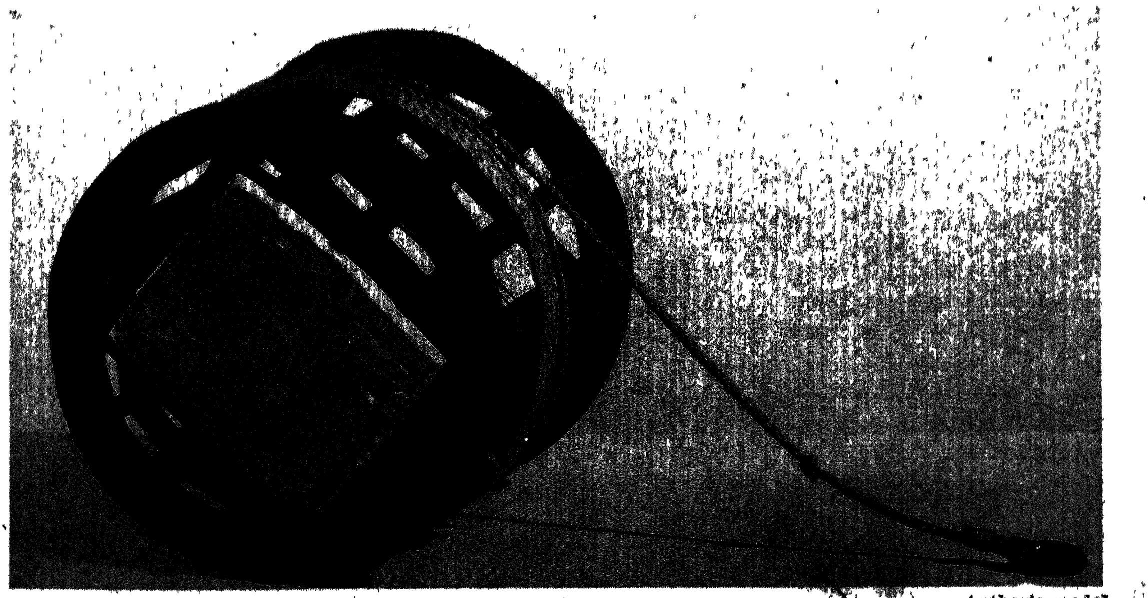
The wheel is not the product of a single genius but the result of slow evolution, and it arose out of man's trial-and-error efforts to move loads from place to place. The wheel of the Western world is a direct descendant of the Egyptian wheel, records of which go back to at least 2000 B.C. From the Egyptians the wheel passed successively to the Assyrians, Phoenecians, Greeks, and Romans and then to Western Europe. The fact that the Greeks claimed to have received the wheel from the gods testifies to their high evaluation of it and probably to the obscurity of its origin. Mention of the wheel is made in the Old Testament (the ark of

the covenant was carried on a cart drawn by oxen) but without description, and it is possible that the ancient Hebrews derived their wheel from the Egyptians.

Apparently a wheel of a different type also evolved independently in Asia. At least the wheel used in the present day in primitive parts of Manchuria, and undoubtedly of ancient origin, is of a type of construction entirely different from that of the spoked wheel of the Egyptians. Variations of this wheel may still be seen in India. In burial grounds in China wheels of many spokes, dated about 500 B.C., have also been unearthed. These Chinese wheels seem to be related to the Egyptian wheel; nevertheless, one is inclined to surmise that the Chinese wheel developed independently of the Egyptian.

How the wheel actually came into being is not known. But certain scraps of prehistoric remains, bits of ancient drawings, and vehicles which have evidently not changed their form for many centuries, permit us to conjecture how one step led to another until the trick of moving burdens on wheels was learned. Two of prehistoric man's mechanical devices must be considered: the runner and the roller.

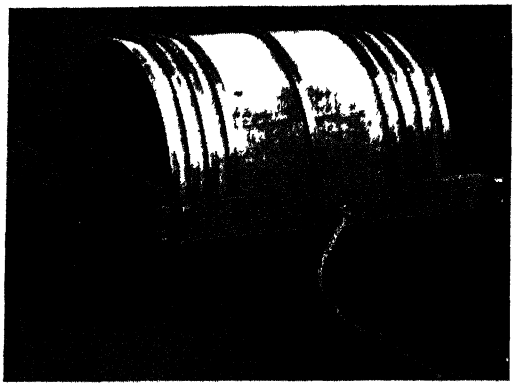
Loads that cannot easily be carried by man or beast may be dragged. Dragging is made easier if the load is mounted on runners. By cutting a forked stick from a tree, primitive man was able to make a serviceable sledge of two runners which bore the load while the main branch served as handle or shaft. Such use of nature's ready-made tool seems to have been common all over the world. A variation of that device is the American Indian's travois, a kind of sled made of two saplings held together with thongs. A pony is hitched between the forward ends of the saplings very much as a horse is harnessed between the shafts of a wagon. By arranging the saplings as runners in parallel, friction was further reduced, and this discovery probably led to the construction of a simple sled. Easy to construct, the crude sled or sledge has served man well and still continues to do so—on farms for moving heavy stones or other unwieldy loads and for construction work where the terrain is too difficult for wheels. In frigid climates the sled has reached all but mechanical perfection. The Eskimo sled, for example, though fashioned by primitive workmen with the crudest of tools and materials, is an example of functional beauty and efficiency, while Russian, Polish, and Hungarian sleighs, drawn by swift horses and lavishly decorated, bespeak the cultures of those peoples. Wherever snow and ice pro-



Author's model

A ROLLING STONE

GRECIAN METHOD OF TRANSPORTING A BLOCK OF STONE. FROM A MODEL IN THE SMITHSONIAN INSTITUTION.



Photograph from U. S National Museum
ROLL OUT THE BARREL
PRIMITIVE WAY OF HAULING A TOBACCO HOGSHEAD.

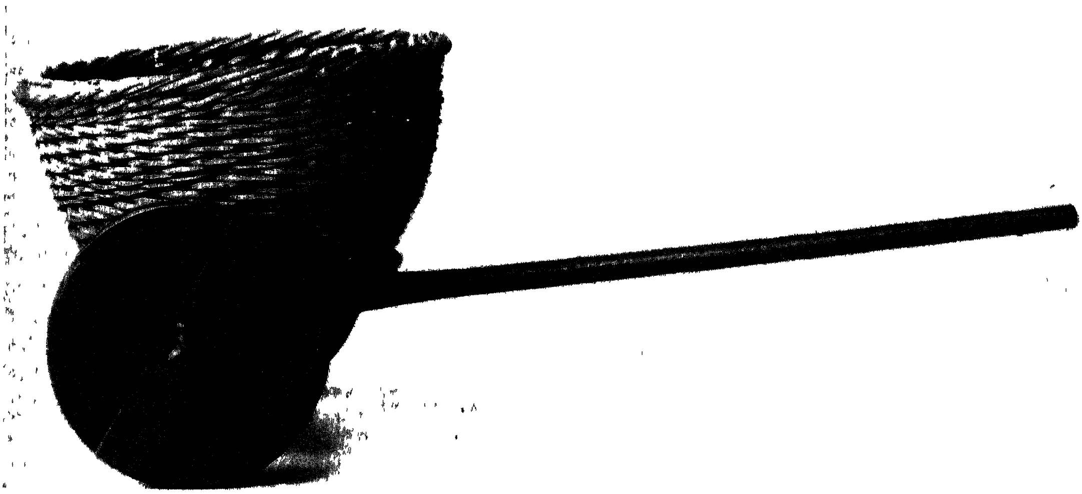
vide a slick surface, the runner is a most useful means of carrying loads but under other circumstances its usefulness is definitely limited.

The roller is commonly said to be the forerunner of the wheel. But how did it evolve? As no one knows, we are free to speculate—which we shall do in the hope of discovering at least a plausible explanation. As in studying natural evolution, one may start with the roller as origin and pursue several paths, some of which end blindly or reach a point beyond which there was no further development. How our hairy ancestors, whose only tool and weapon was a club, discovered the friction-overcoming qualities of a roller is anybody's guess. Rounded stones roll down hill; the feathery seeds of the tumbleweed roll when driven by the wind; a log may be rolled with greater ease than dragged head-on. Some such observation no doubt led primitive man to shape his loads, when possible, in spherical or cylindrical form.

That the rolling-load principle was highly developed and carried over into civilization is attested by the manner in which the ancient Greeks transported to Athens the marble blocks for their magnificent temples. The columns which support the roofs of their buildings were quarried miles away and shaped into cylinders there, each section being about twice as long as the diameter of the circle. Holes were drilled in the ends of the cylinder at the pivotal center. A wooden framework was then fashioned around the cylinder, with pegs that fitted into the drilled holes. Then, by pulling the framework, the cylinder was easily rolled to the temple site and there lifted into place. Here we find a hint of the wheel hub revolving around an axle. But it is not a wheel capable of carrying a load. It is itself the load and merely rolls. The identical arrangement has been used until recently in American transportation. Before railroads were common, huge casks of tobacco were fitted into frameworks like those of the Greeks for moving pillars. Mules were hitched to these casks and so were rolled for miles over country roads to the steamboat landing where they were taken aboard.

The Greeks also invented a device for moving square and oblong blocks of marble and stone. It was a kind of skeleton cylinder made of wood and closely resembled a squirrel cage, in which the block of marble was encased. It consisted of two strong hoops connected at their peripheries by equally-spaced parallel sticks. Around the cylinder the movers wrapped a line, which, when pulled by oxen, unwound itself and rolled the cylinder with its load. In this contrivance there is neither hub nor axle. But the hoops, running parallel to each other on the ground, remind one of the rims and tires of two wagon wheels. Still, this is a rolling load and in no sense a wheel. The rolling load is serviceable today—think of barrels made to roll and of the huge spools on which telephone cable is wrapped and transported—but in the evolutionary scheme it does not lead us to the wheel.

Another early use of the roller was to place it under a flat-surfaced object and then push or pull the load. The roller had to be replaced over and over again, which meant stopping, carrying the roller forward, lifting the front end of the load, and placing the roller again beneath it. Two rollers made the task a bit easier, and three rollers obviated the necessity of lifting the forward end of the load each time a roller had to be reinserted. With the aid of the roller the Egyptians built their mighty pyramids, moving huge blocks of stone up inclined planes, and with exactly the same technique we now move heavy pieces of machinery, and even houses, from place to place. But that is as far as the roller, of itself, developed, unless one wishes to marvel at the smooth efficiency



Photograph from U. S. National Museum

ROMAN CART

of the roller bearing, which is still a roller and not a wheel.

We make, therefore, a third exploration, starting with primitive man's roller which, in all likelihood, was the section of a tree trunk from which the bark had been peeled. This roller he used to move his sledge, crudely made of two runners joined by cross pieces. On this sledge he moved heavy objects that could not well be moved alone. Coming to difficult spots, he placed a roller under the runners; and that greatly eased friction. With repeated use the roller would wear down where the runner passed over it. Eventually two grooves would ring such a roller where the runners came in contact with it. The deeper these grooves, the more efficient such a roller becomes for the reason that the circumference of the roller which passes over the ground is greater than the circumference traveled by the runner. Assume that a roller has a circumference of 1 foot. If the runner is 3 feet long, the roller will move forward 3 linear feet before it has to be changed. In the meantime the runner has gained an additional 3 feet by passing over the roller. Thus the load has been advanced 6 feet with one change of roller. Now assume grooves worn into this roller so deep that the circumference of the grooves is $\frac{1}{2}$ foot. Six revolutions of the roller would be made before the need of changing the roller arises, thus advancing the roller 6 feet, and the runners would have advanced $6 \times \frac{1}{2}$ feet or 3 feet, making a total of 9 feet advancement of the load. Thus, the worn runner, though not as strong as when new, would be 50 per cent more efficient in its load-advancing capacity than one of the same size not worn down.

Eventually the grooves would wear so deeply that the roller would break. In replacing it with a new one, it is conceivable that a man with even a glimmer of intelligence would cut grooves into the new roller like those of the worn roller when it was still at the height of its efficiency. Having gone through this process several times, he must have asked himself sooner or later what useful purpose, if any, was served by the mass of wood lying between the grooves. Experimentally perhaps, he removed it with his axe —and produced a roller much lighter in weight. Such a roller is, in general design, the same as that of the two car wheels held together with an axle, now used on railroad cars.

The next step was a crucial one—holding the roller (now wheels and axle) in place underneath the runners. It was achieved no doubt by means of pegs driven into the underside of the runner near its mid-point. When that was done, a crude cart had been invented.

Further progress was technically impossible until the saw was discovered, which was comparatively late. According to Greek tradition the saw came into being out of the

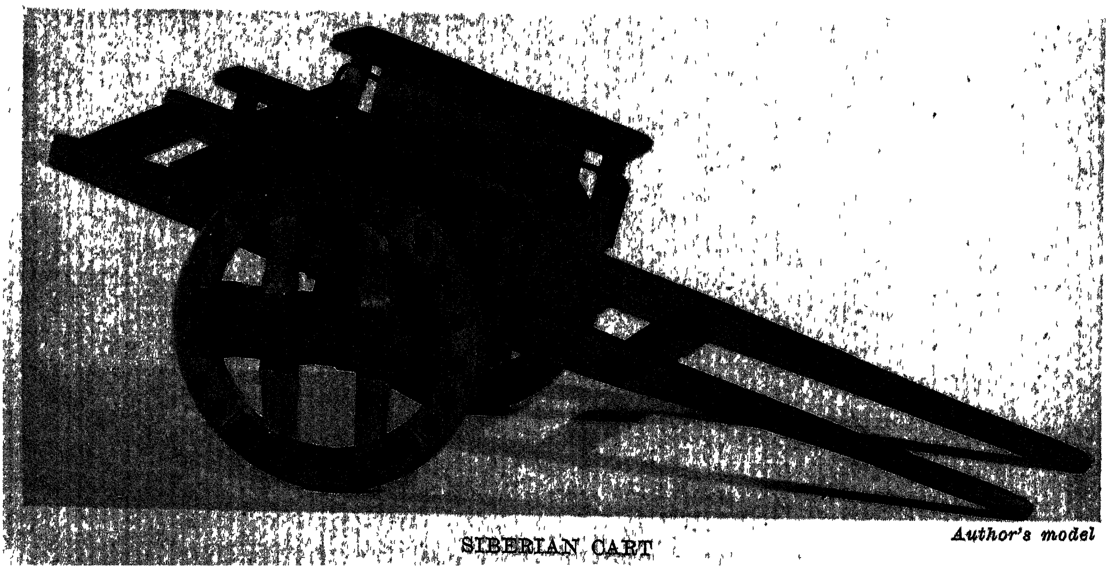
efforts of an early metal craftsman to model the jawbone of a serpent in iron. True or not, the metal-toothed tool opened a new field of technology for man and made possible, among other things, the sawing of a disc from the trunk of a tree. By drilling a hole at the center of the disc, the end of an axle could be driven into it. The larger in diameter the disc and the smaller the axle, the more efficient would be the unit consisting of two wheels and axle. With the greater ease of transportation made possible by such a pair of wheels, interruption caused by the need of changing rollers was obviated, and that made it possible to use animals to pull the load. Distance was shortened, time and energy were saved. All this no doubt encouraged the interchange of goods—the beginning of commerce. And along with the development of the wheel and axle probably also went the further refinement of the sledge, so that it became a chassis and body, and the entire ensemble, a cart.

Accident may have led to the discovery that a wheel may be made to revolve about the axle instead of with it. One can imagine that a wheel, worked loose from its axle, might temporarily have been held in place by means of a peg driven through the distal end of the axle. Then why not construct the wheel and axle so that the axle would remain affixed to the chassis and permit the wheel to revolve about it? Of course the wheel would wobble unless the axle fitted the hole with a fair degree of precision That the mastery of this improvement was not easy is implied in some of the wheels of the Orient—Manchuria, China, India—for some of these wheels are still fixed permanently to the axle.

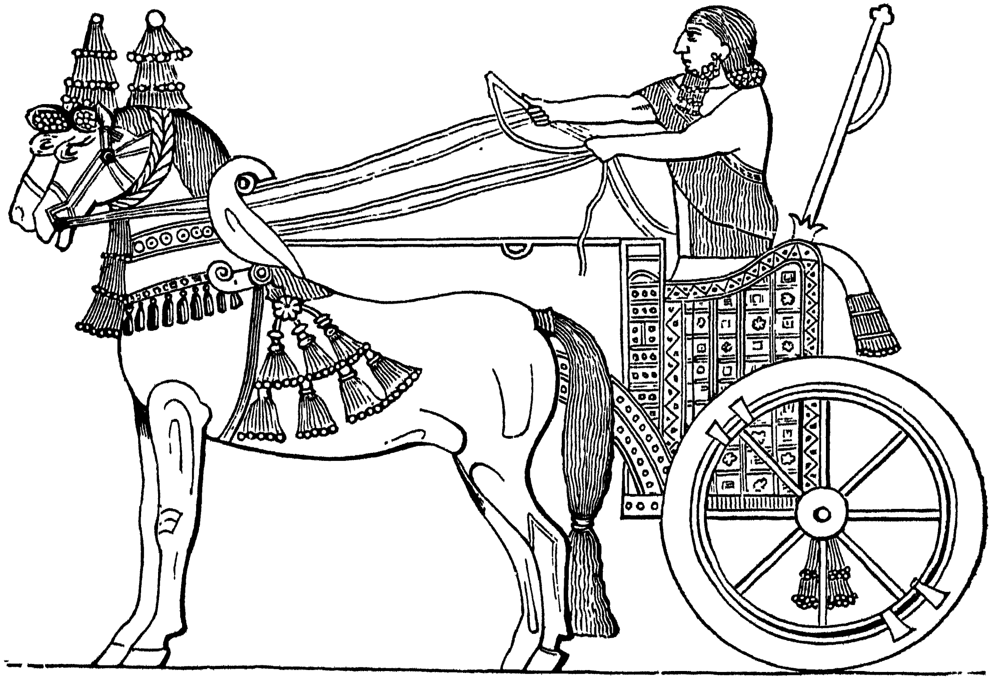
At its best the solid disc wheel sawed from a tree trunk is heavy, clumsy, and not easy to make. The size is limited by the diameter of the tree trunk—and size is important, for a large wheel travels more easily over rough terrain and wears out less quickly than a small wheel. Furthermore, parallel saw cuts are more difficult to make through a large log than a small one. Weight is reduced by cutting the disc as thin as possible consistent with strength, but a thin wheel presents less revolving surface for the axle than a thicker one and hence will more easily wobble. These limitations were overcome when man became a little more adept with tools and learned to use slabs of wood, or boards, which in turn led to the development of the spoked wheel.

The Spoked Wheel

Two boards fastened together on their flat sides with the grains crossing at right angles are very strong (we are just beginning to appreciate the strength of laminated plywood). If the boards are 6 inches wide, a 6-inch disc can be cut from them which will be reasonably strong. A hole drilled in the center makes the disc a wheel. If the wheel



SIBERIAN CART *Author's model*



Photograph from U. S. National Museum

ASSYRIAN CHARIOT

is to be larger, say 18 inches, three 6-inch boards laid edge to edge and crossed by three similar boards at right angles may be tightly joined for the purpose. Still stronger would be a wheel made of three such layers, the grains of the wood in this case crossing at angles of 60 degrees. Wheels of that type are actually known to have existed, for example, on farm carts of the Roman Empire period.

The greatest wear of such a wheel would be at the rim. A tire carried around the rim would protect it, and when worn out, could be replaced, thus prolonging the usefulness of the wheel. How the tire first came to be used is shrouded in mystery. It is conceivable that a split sapling may have been fastened to the outer edge of the disc. There is a hint of this construction in an old Egyptian wheel in which the fellies are made of inner and outer parts and are lashed together with thongs. This may have been a carry-over of the more primitive method of lashing an outer to an inner rim.

Whatever the origin of the tire may have been, it must soon have become evident that, with its use, the outer segments of the discs making up a three-layer wheel, were now superfluous. Leaving them out would produce a wheel of six wide spokes. This wheel would be much lighter and yet with a "hub" wide enough to assure steadiness. That such was the origin of the spoked wheel is conjecture, yet not without some historic basis. Certainly it is significant that Egyptian wheels and their descendants have either four or six spokes or multiples of four or six. In rural sections of South Carolina there are still to be seen home made carts with wheels of the three-board variety. This wheel is surely not a direct descendant of primitive man's wheel but was doubtless thought out independently by ingenious mechanics forced to make their own wheels.

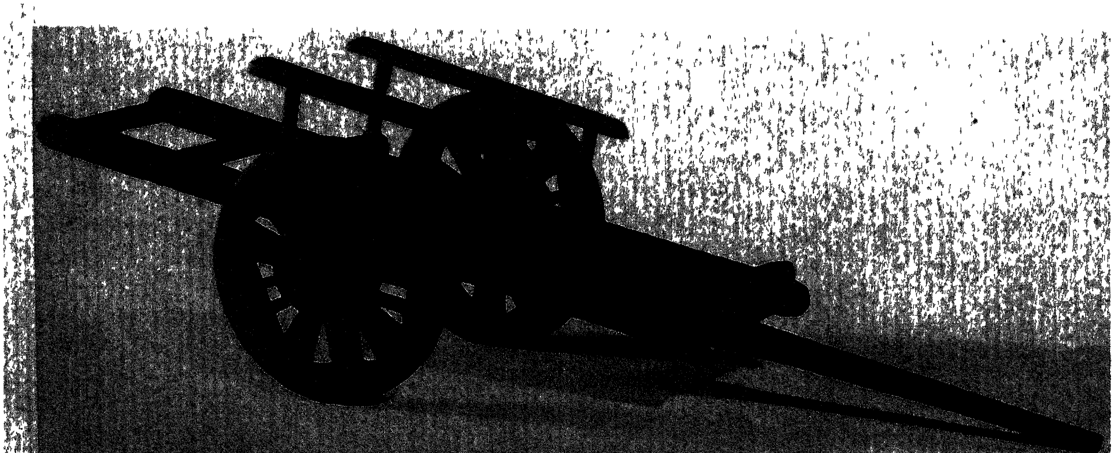
Three boards overlapping at 60-degree angles form six spokes, but the ends of these spokes are not in alignment unless warped into line, which has its disadvantages. But six independent spokes can be aligned. That may be done by constructing the hub separately so that the spokes radiate from hub to rim. Once the trick of putting spokes into the hub had been mastered, the number of spokes could be increased without disturbing the symmetry and balance of the wheel. Thus the way was opened for further evo-

lution of the wheel. This principle of wheel making has stood the test of time and while refinements have been added to the wheel's lightness and strength and general efficiency, no radical change in the wheel has been made for perhaps 4000 years, with perhaps the single exception of the bicycle wheel. In the ordinary wheel the load carried by the axle rests primarily on the spoke directly beneath it and partially on the spokes to either side of it. To be sure, a well-constructed wheel is a single unit in which all parts function at all times, but the weight is mostly a downward push. In the bicycle wheel, however, the load at the hub is suspended from the spokes above the hub. In fact, none of the spokes is completely "idle" at any time, for the rim is somewhat flexible, and a given spoke exerts varying degrees of "push" and "pull" according to the position of the wheel. In principle it is like an arch bridge, the upper part of the bicycle wheel rim being the equivalent of the arch. Instead of steel spokes, flexible cords might just as well be used, though such a wheel would lack steadiness. The lightness of the bicycle wheel makes for easy maneuverability and is peculiarly adapted for a self-propelled vehicle where every surplus ounce of weight and every bit of friction counts.

Another refinement of the modern wheel is the roller bearing. But this represents simply a means of overcoming friction between axle and hub. The pneumatic rubber tire is an innovation (as history is measured) and has made modern motor travel possible. Aside from a few such refinements, the wheel has remained unchanged for many centuries.

The Egyptians carried the spoked wheel to a high degree of perfection. Pictures of their chariots abound, but they do not satisfactorily depict the mechanical principles. Fortunately a few original chariots have been preserved; one from the era of the Ptolemys is in the Florentine Museum. Apparently chariots were used primarily for war purposes and for racing. Consequently they were made light and durable and were drawn by horses. There is little evidence of the use of the spoked wheel for domestic purposes in ancient Egypt, for their roads were designed for foot travel and beasts of burden. The Greeks added little if anything to the wheel, but they did make their chariots of metal and decorated them, sometimes profusely. Like the Egyptians they used the chariot primarily for war and for racing, a very important part of Greek life.

From the Greeks the wheel passed to the Romans unchanged. Roman chariot racing is familiar to every school boy, and Roman roads have become a byword of enterprise and durability. But the Romans extended the use of the wheel enormously. The great contribution of Roman engineers was the discovery of the method of swiveling the front axle. Four-wheeled vehicles had been used by the Greeks, but they were awkward because the front wheels were kept as rigid as the hind wheels, and turning corners meant wasteful skidding of wheels to say nothing of the strain of the side thrust on



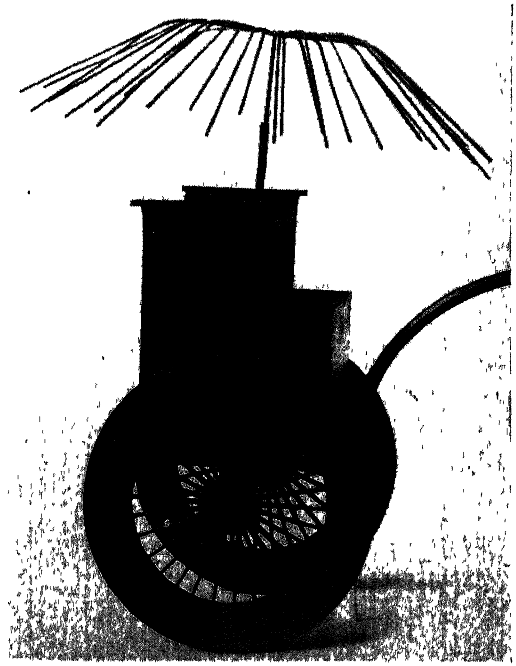
Author's model

PERSIAN FARM CART

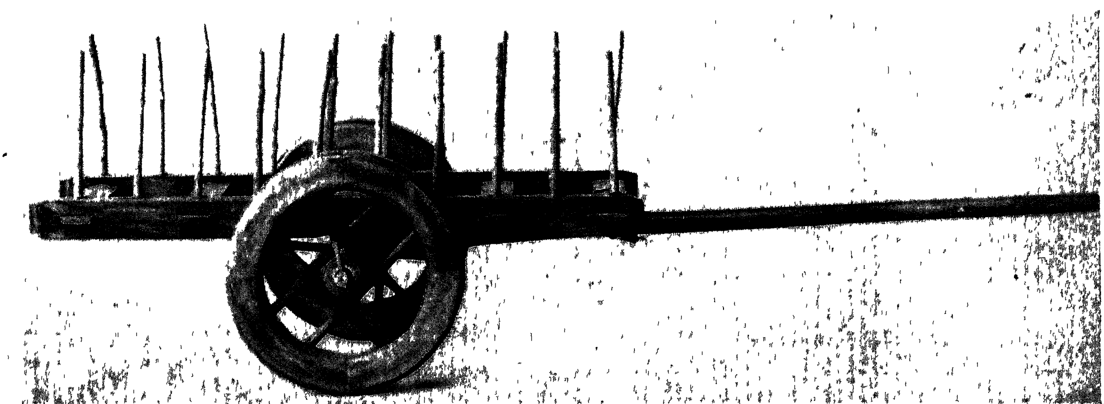
them. Pivoting the front axle opened the way for larger, more commodious vehicles and greatly stimulated passenger use of vehicles. Unlike roads of previous civilizations, those that led to Rome were made primarily for peacetime traffic. Roman travelers were familiar with the rheda, a kind of omnibus or stage, and of private vehicles there were many. The Romans also used the horse for domestic vehicles which, too, was an innovation.

With the fall of Rome the spoked wheel all but disappeared from the Western world, incredible as that may seem. The crude disc wheel was again the only type employed, and for hundreds of years nothing better was at hand. Roads were practically nonexistent, and the chief use made of wagons during the early Christian centuries was for the transportation of the hordes of Gauls and Germans in their great migrations. Goods and chattels of the wandering tribes were carried in huge wagons drawn by oxen, and when the going was difficult, women, children, and the sick rode on them too. At night the wagons provided shelter. They were in effect like the covered wagons of the American pioneers. Wagons of this kind were also used in the numerous wars of that period. By placing them end to end an effective wall of protection, or fortress, was built.

The lowly ox was the draft animal of the early Middle Ages. No one thought of humbling the pride of the stately horse by hitching him to a cart or wagon. He was considered to be a beast fit only for battle and for bearing on his proud back kings and noblemen. But in the twelfth century this sentiment changed, and men began to use the horse for pulling purposes. The horse is a quicker, more responsive animal than the lumbering ox, and the wagons of that day were not geared up to him. So the growing custom of using the horse for draft purposes necessitated refinements and improvements in wagon construction. Slowly, laboriously the spoked wheel was reinvented, or rather reintroduced, for memories and remnants of the wheel of a destroyed civilization must



Photograph from U. S. National Museum
CHINESE CHARIOT



Photograph from U. S. National Museum
EAST INDIAN VILLAGE CART

Photograph from U. S. National Museum

A ONE HOSS SHAY

have remained here and there. So far-reaching was the effect of this new use of the horse that it may be said to mark an epoch in land transportation, particularly in the development of the spoked wheel. Soon the trade of wheelwright attained high dignity and became one of the most technical and honored of the crafts.

As craftsmen became more skillful and the demands for more rapid transport increased, lighter and stronger wheels were perfected. Much argument and debate ensued as to the size, shape, and dimensions that a wheel intended for a given purpose should have. Methods of fastening the fellies and spokes and of inserting the spokes into the hub were hotly discussed. The number of spokes that a wheel should have was a grave question, and whether or not a wheel should be "dished," and how much, was a serious engineering problem. The iron tire greatly improved the wheel as did also the metal lining inside the hub.

No one has better expressed the spirit of the craftsman than Holmes in the delightful story of "The Deacon's Masterpiece" which begins with the rollicking lines:

> Have you heard of the wonderful one hoss shay
> That was built in such a logical way,
> It ran a hundred years to a day
> And then, of a sudden it—ah, but stay—

The deacon had noticed that "a chaise *breaks* down but doesn't *wear* out," so he set out to build one that would not break down, by the simple expedient of making "the weakest place as strong as the rest."

> The deacon inquired of the village folk
> Where he could find the strongest oak
> That couldn't be split nor bent nor broke.

He searched out "steel of the finest, bright and blue," while the leather parts came "from tough old hide, found in the vat when the tanner died." Long did that chaise serve the deacon and his children and never a repair was needed until one day, after a century of usefulness:

> It went to pieces all at once,
> All at once, and nothing first,
> Just as bubbles do when they burst.

A fine example of the wheelwright's art!

ECONOMIC ENTOMOLOGY IN SOUTH AMERICA

By EDSON J. HAMBLETON

THE tropics of South America offer almost every conceivable type of ecological habitat: from torrid jungles to snow-covered mountain ranges and from the arid desert land to swampy flood plains. The flora and fauna of these regions are more interesting and by far more complex than those of the temperate zones. For the insect collector and taxonomist the Neotropical fauna has long been the source of much attraction. It is in the tropics or subtropics where size, color, and morphological structure of insects reach their extremes. Many of the classical species of early systematists were specimens taken in the tropics. But despite this interest, so manifest ever since the time of Linnaeus and Fabricius, entomologists now working in the tropics are constantly confronted with innumerable problems related to the identification of the common insect fauna. Many of the described species from South America that are located in European museums are inaccessible and of somewhat doubtful status owing to changes in present-day methods of study. This situation will gradually tend to improve. For example, increased interest in biological sciences has been notably demonstrated in Brazil by the appearance of new journals and scientific publications during the last fifteen years. Agricultural colleges and universities are improving their teaching staffs while an ever-increasing number of students seek courses in or related to zoology and entomology.

Many outstanding contributions to medical entomology and parasitology have been made in South America since the beginning of the present century. Men like Oswaldo Cruz, Adolpho Lutz, Arturo Neiva, and Costa Lima have long been the source of much inspiration to their fellow workers and students throughout Brazil. Entomological problems relating to health and sanitation, insect disease vectors, and systematic and biological work on various families of disease transmitting species have occupied the attention of the leading scientists in the country. But not until about the year 1924 was any particular emphasis given to insect pests of agricultural importance except for the ubiquitous leaf-cutting ants and other insects affecting fruits and vegetables. Coffee, sugar cane, and cotton (three of the leading crops) until that time had received little entomological attention. Nearly one-half of all entomological contributions up until 1924 concerned insect taxonomy and medical entomology. During 1924 and the following years, numerous publications appeared relating to the coffee berry borer, *Stephanoderes hampei,* an imported species introduced in coffee seed from Java several years prior to that time.

Economic entomology seems to have gained a sudden impetus through the ravages of the berry borer in the State of São Paulo, Brazil. From the activities of a Commission appointed to formulate ways and means of studying and controlling the pest, there resulted the development of the *Instituto Biologico de São Paulo,* today one of the best-known scientific institutions in the country.

In spite of all efforts on the part of the Federal government and the State of São Paulo to check the spread of the coffee berry borer, the insect continued its destructive march into the richest coffee growing areas of the State. By 1929, losses were mounting to such an extent that many growers began to abandon their plantations. This resulted in an increase of the pest at a time when market conditions were at their worst. Control measures by fumigation and clean cultivation became financially impossible, and a crisis developed. During the ensuing years the stock of coffee in government warehouses became a drug on the market. Growers were face to face with a situation never before encountered in the history of coffee production. In the severely infested areas the cost of production had naturally increased owing to reduced yields of an inferior product and to the growers' obliga-

tion to fumigate their entire stock and conduct clean-up measures in their plantations after harvest. Government regulations made it imperative that abandoned coffee trees be removed since these served as a constant source of infestation.

Thus the problem of the coffee berry borer confronting the São Paulo coffee grower became more complex. The majority of these growers in the stricken area had not previously experienced the difficulties involved in insect control, for coffee, their chief crop, had suffered little or no damage of economic importance from other insect enemies. The less fortunate growers went bankrupt; others chose the path of least resistance, decided to abandon coffee cultivation altogether and pursue what then appeared to be a more lucrative system of agriculture never before attempted in their particular localities.

From coffee, many turned to cotton cultivation; while corn and various other crops found their way into an ideal form of crop rotation which had not been feasible under the one-crop system, in operation since colonial days.

The eradication of many million bearing and abandoned coffee trees literally revolutionized agricultural practices. Throughout this area the berry borer infestation diminished considerably, and those who survived the crisis and continued to grow coffee were soon convinced that practical control measures were effective in maintaining the borer infestation at a minimum.

For twenty years the coffee berry borer gradually extended its range in all directions, and today there remain but few areas in the State of São Paulo where it is not present to some extent. In the southwestern portion of Minas Geraes, the borer invaded coffee plantations as early as 1932. However, it has not constituted as serious a menace there as in São Paulo, nor has it been able to spread to other more remote coffee producing areas in the State, owing primarily to the nature of agricultural practices, local topography, and shipping restrictions.

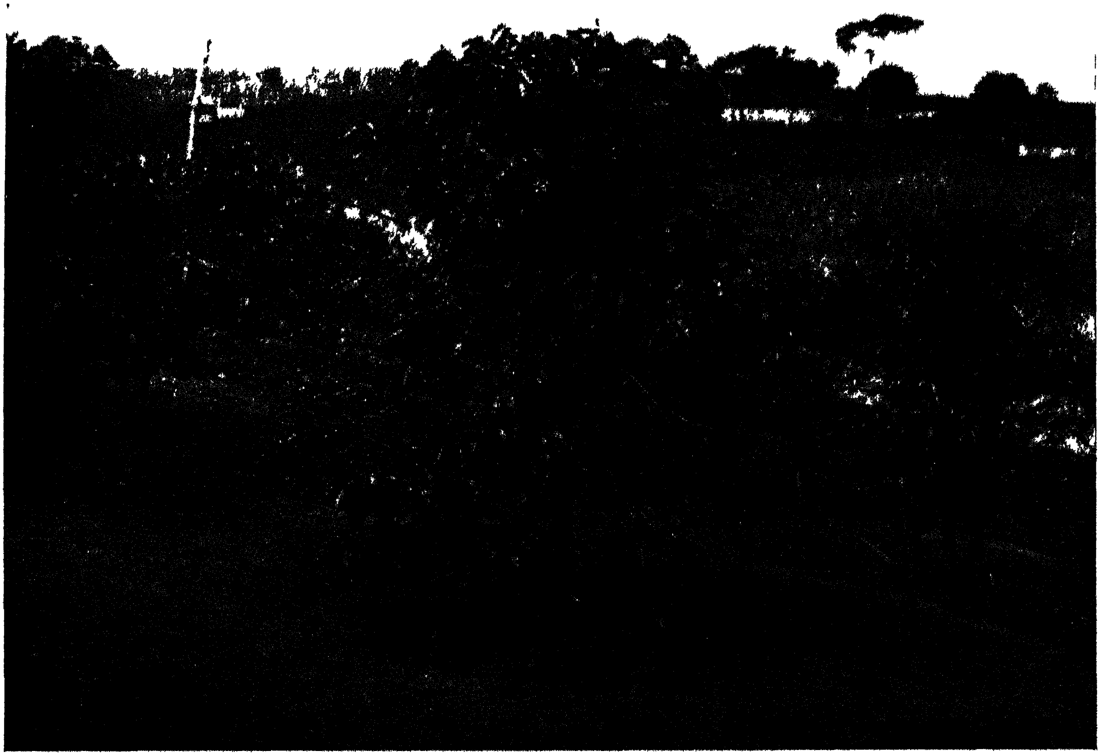
A NEST OF THE LEAF-CUTTING ANT, *ATTA SEXDENS RUBROPILOSA*
PARTIAL VIEW SHOWING LOOSE EARTH AND NUMEROUS ENTRANCES IMMEDIATELY ABOVE THE OCCUPIED AREA.

CROSS SECTION OF NEST AFTER EXTERMINATING COLONY WITH CARBON DISULPHIDE
AN EXCAVATION OF THE NEST SEEN IN THE PREVIOUS ILLUSTRATION SHOWS THE REMAINS OF THE FUNGUS GARDENS IN THE LARGER CHAMBERS. THE TWO OBLIQUE CHANNELS WERE MADE FOR APPLYING THE FUMIGANT.

The coffee berry borer control program developed into the most important entomological project in Brazil. From the time of its inception, much emphasis has been given to biological control following the introduction and large scale production of the natural enemy, *Prorops nasuta,* from the Uganda Protectorate in 1929. This hymenopterous parasite readily adapted itself to São Paulo conditions and after a few years was established in several areas of the State. Fumigation of infested fruits at harvest time and the "clean-up" or removal of fallen berries and those overlooked in the trees at picking time are still considered of paramount importance in the control program.

When it was once confirmed that the parasite population had shown indications of increasing under field conditions, there soon developed a widespread demand for the parasite. Consequently, small colonies were distributed among growers as fast as they became available. Small rearing units were established on individual fazendas where necessary instructions were issued to growers to facilitate the rearing and liberation of their own parasites. Facilities for higher production were developed at the Instituto Biologico in Campinas, and this organization co-operated in the distribution and instructional work to such an extent that today parasite activity may be observed on practically all the infested plantations in the State.

Irrespective of all the effort exerted and of eagerness on the part of coffee growers to succeed in this new undertaking, no very concise conclusion has yet been reached as to the actual benefit derived from the parasite. This is due to a number of other factors, any one of which may have been partly responsible for decline in infestations of the berry borer. Parasite populations as a rule generally increase or decrease according to the density of the host population. This holds true for *Prorops nasuta* under São Paulo conditions. Climatic conditions



COFFEE TREES JUST BEFORE HARVESTING
ALL VEGETATION AND TRASH ARE REMOVED AND THE SOIL SMOOTHED OFF BEFORE GATHERING THE BERRIES.

and the time and nature of the harvest vary considerably from one zone to another throughout the vast coffee growing area of the State. The activity of the parasite may be interrupted at harvest time when conditions for its propagation are conducive to a rapid increase in population. The fumigation of the berries at picking time is followed by an obligatory clean-up throughout the groves to eliminate any remaining berries that may harbor the coffee berry borer through the winter season. Incidentally, the Uganda wasp is entirely dependent on the berry borer for its survival and the number of wasps gradually diminishes as its food supply runs short.

In order to carry the wasp through the winter season, it is absolutely essential that borer-infested fruits be accessible at all times. This is accomplished by placing infested fruits, with or without parasites, in small screened insectaries where sufficient heat is provided for reproduction. Otherwise the adult parasites, like those in the field during the winter, practically cease to oviposit and act as predators as long as weather permits.

In some areas of the State the parasite will probably be found more effective than in others. But despite any doubt that may still exist as to its usefulness, the parasite program has gained much prestige in agricultural circles. It has done much to foster the promotion of further interest in applied entomology in Brazil.

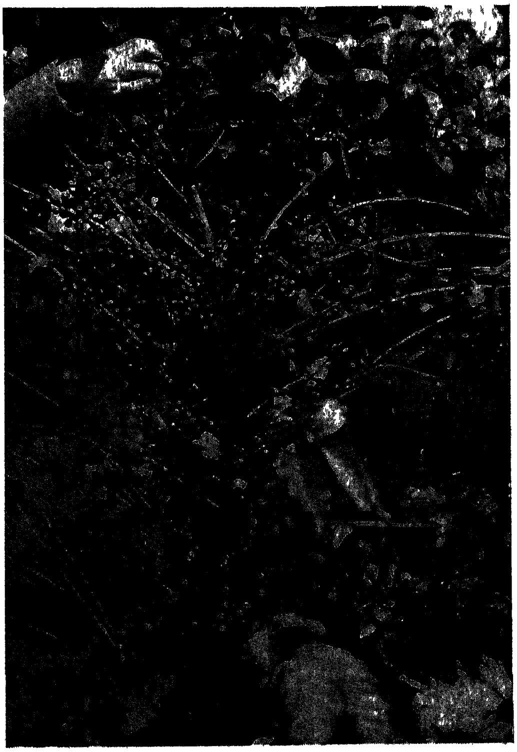
Cotton is one of the oldest and most important of all crops grown throughout the northeastern states of Brazil where it constitutes the chief source of income over a very extensive area comprising the larger portion of the States of Pernambuco, Parahyba, and Rio Grande do Norte. Although the climate, topography, and fauna of these three states are much alike, in each there are quite distinct areas in which conditions vary considerably and the problems confronting the growers are indeed complex. Several kinds of cotton are grown. Some localities where rainfall is more abundant

are suitable for the herbaceous varieties, whereas in the more arid or semiarid areas only the perennial cottons are cultivated. Where rainfall is plentiful, insect enemies are likewise more troublesome. Some of the same insect pests occur in the perennial cotton grown in the more arid regions, but damage there is less severe. The plantings are usually small and often widely separated and are located where soil moisture is most abundant. Control of some insects is obtained by the simple cultural methods where insecticide applications are not often satisfactory.

The cotton borer, *Gasterocercodes brasiliensis,* may be found throughout most of the cotton growing areas in Brazil. In the north it is a pest of both annual and perennial cottons but causes more severe loss to the herbaceous varieties grown where temperature, rainfall, and soil conditions are more favorable to its propagation. But even in the more arid regions this species has a general distribution and despite less favorable conditions it is present to some extent in practically every planting of perennial cotton. Because rainfall through the Sertao (semiarid region) is very irregular over a period of years, cotton seed must be planted immediately following the heavy rains that may come no oftener than once in several years. The cotton borer is readily attracted to new plantings and thus inflicts severe damage during the first season's growth. To insure against total loss, the fields are heavily seeded, and thinning is delayed just as long as possible. If the

INFESTED COTTON FIELD

UPLAND COTTON IN SÃO PAULO INFESTED WITH THE COTTON ROOT BORER, *Gasterocercodes brasiliensis.*



COFFEE BERRIES

grower is successful in maintaining his plants during their first season, neither drought nor borer attack are likely to cause him much further concern. If given a chance, the plants develop rapidly and for several years will usually tolerate both insect attack and scanty rainfall. Four- or five-year-old cotton plantings are seldom free from borer injury. At this age their branches usually become so infested that they are easily broken, and such plants can no longer be cultivated economically. In the areas where rainfall is plentiful, as in parts of Pernambuco, Bahia, and farther south in Minas Geraes and São Paulo, the cotton borer often occasions serious losses early in the growing season. In these areas only the herbaceous cotton is cultivated. Being less resistant to attack, it must be thinned early and it more often succumbs to borer attack. Here again cultural control methods are practiced and, where conducted systematically over a wide area, generally prove quite effective.

In recent years, some attempts have been made to control the cotton borer by means of

COTTON GRADUALLY DOMINATES AS FOREST LAND GIVES WAY TO MODERN AGRICULTURE
THIS IS A TYPICAL SCENE IN A WOODED AREA IN NORTHWESTERN SÃO PAULO, 1938. THE LAND HAS BEEN CLEARED AND ALL BUT THE BEST TIMBER HAS BEEN FELLED AND BURNED AND THE SOIL PLANTED TO COTTON.

arsenical sprays with a reasonable degree of success. Control of this insect with poison dusts or sprays has not been universally adopted on account of the expense involved and the difficulty of making effective treatments during the rainy growing season.

A closely related species, *Gasterocercodes gossypii,* occurs in Peru and Ecuador. Legislation which prohibits the cultivation of ratoon cotton and limits the period during which plants may remain in the field has proved very successful for the control of this insect in northern Peru.

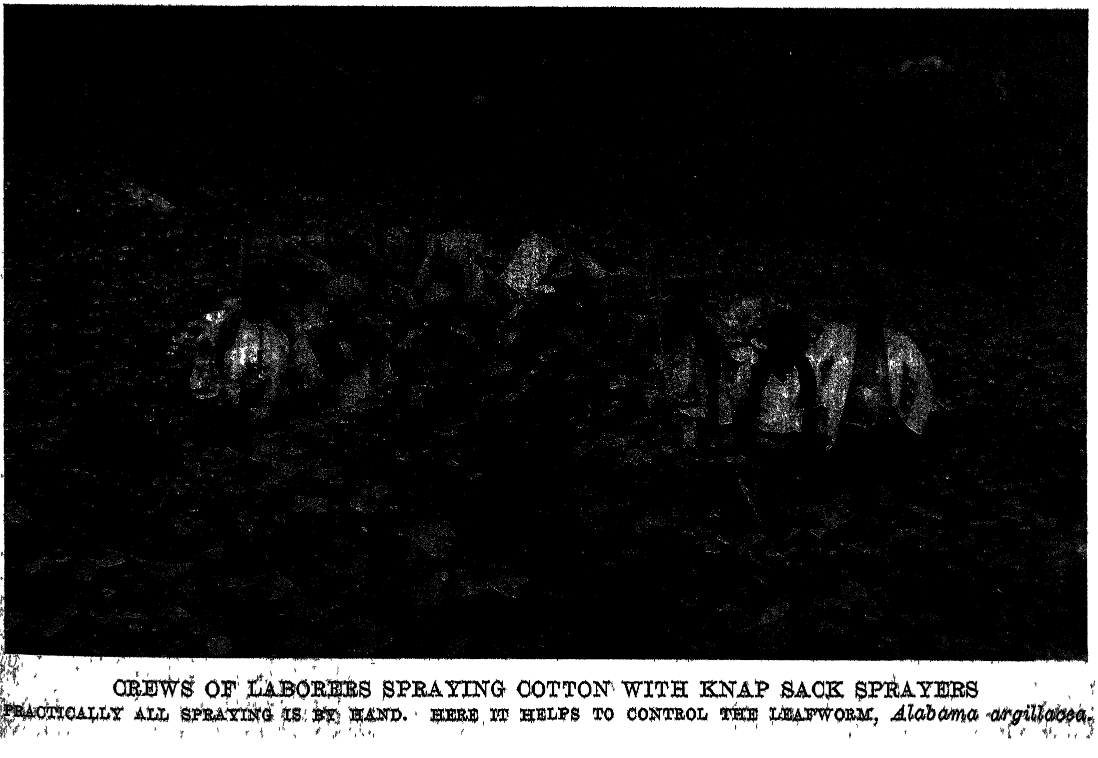
The cotton leafworm, *Alabama argillacea,* is the best-known pest of cotton in Brazil. It has always been a constant menace, appearing each season at more or less the same time in any particular region. Propagation of this species is rapid, and within a short period infestation is widespread. During adverse weather cotton growers are seriously handicapped in applying arsenical sprays. The leafworm infestation coincides with the rainy season, and anyone who has ever undertaken insect control during prolonged rainy spells can readily appreciate what the Brazilian cotton grower must contend with in protecting his crop. All spraying is done by hand because power sprayers cannot be operated on hilly terrain and on wet soil. Hand labor is also considered more economical where it is readily available. Large growers must necessarily be well stocked with hand sprayers, prepared to make an application at a moment's notice, or to repeat an application as occasion may demand.

In Brazil the leafworm is attacked by a host of natural enemies, including both ecto- and endo-parasites, insect predators, and birds. But only after much damage has occurred and the temperature subsides is one able to appreciate the role they play in natural control.

In Peru the cotton leafworm problem is quite distinct. Moths invariably invade the valleys in the northern provinces and are especially troublesome in the Chira and Piura valleys. The bulk of the cotton crop

is grown in approximately thirty valleys extending along the coast almost as far south as the Chilean border, but only upon rare occasions is the insect ever observed south of Lima. Consequently, it is not considered of any importance elsewhere in the country. It has always been somewhat of a mystery why the insect has confined its activity to the valleys in the north. Although most of the valleys are small and separated by wide extensions of desert land, such factors would hardly explain its absence farther south. Climatic conditions vary considerably in the different cotton-growing valleys where rainfall is negligible. But here again such differences as temperature and relative humidity would not seem to be of sufficiently great importance to limit the insect to its present destructive range. The climate along the coast is subtropical, the winter season being rather humid, while the summers are very dry. In the Chira and Piura valleys to the north the cotton crop is usually harvested before planting gets under way in the Rimac valley at Lima and at Canete, some 160 kilometers farther south. In other words, there appears to be but slight possibility that moths of *Alabama argillacea* would migrate south to any great distance from Piura at a time of year when mean temperatures average about 60 degrees F. at Lima and Canete and before cotton is suitable for attack. Other atmospheric conditions resulting from the effects of the Humboldt current, such as the formation of dense clouds that cover the coastal lowlands during the winter months, may exert some influence as barriers against migrating moths. The Andes Mountains to the east also serve as important barriers.

Another South American insect of world-wide distribution and long considered one of the most important pests of cotton is the pink bollworm, *Pectinophora gossypiella*. Since first reported in Brazil, this insect has extended its range to include all of the more important cotton growing areas in the country. Annual losses have never been satisfactorily calculated inasmuch as they vary greatly from one area to another and in the different varieties cultivated. In the herbaceous or Upland cottons grown in areas of favorable climatic conditions, the damage is exceedingly high. Losses seem to be even more severe in seasons of excessive rainfall as observed in the State of São Paulo. Aside from the destruction of seed and fiber, con-



CREWS OF LABORERS SPRAYING COTTON WITH KNAP SACK SPRAYERS

PRACTICALLY ALL SPRAYING IS BY HAND. HERE IT HELPS TO CONTROL THE LEAFWORM, *Alabama argillacea.*

DEFOLIATION BY THE COTTON LEAFWORM, *ALABAMA ARGILLACEA*
ALTHOUGH EARLY DAMAGE REDUCES YIELD, LATER DEFOLIATION SOMETIMES AIDS IN HARVESTING THE CROP.

siderable loss is occasioned through shedding of squares infested with pink bollworm larvae early in the season before bolls are far enough developed to be attractive to the egg-laying moths.

No organized campaign to control the pink bollworm has ever been attempted in Brazil. Indeed, if such an undertaking were to evolve, it would require a large corps of field inspectors to contact growers, to visit fields that extend through most of the cultivated farming areas of the country, and to maintain vigilance at cotton gins, oil mills, and storage houses. In fact, a venture of this nature would have to include the co-operative efforts of practically everyone connected with the cotton industry. Perhaps the most difficult task would be the clean-up and destruction of crop remains after harvest. On a few of the larger estates this type of control is practiced, but as a rule no effort is made among the thousands of smaller growers to do more than burn the stalks some time after the cotton is picked. Since it has been estimated that roughly 90 to 95 per cent of the infestation originates from bollworm moths that have emerged from crop refuse left in the field, clean-up measures are of the most vital importance in any kind of a control program to suppress the pink bollworm in Brazil.

Perhaps too much value and "wishful thinking" has been placed on seed fumigation as a means of pink bollworm control in preventing its spread into newly developed cotton growing areas in São Paulo. It is rather unfortunate that this general opinion has so long prevailed, for regardless of the fact that all cotton seed has been controlled and fumigated by the State for several years, not a single area is free from the insect. Seed fumigation does, nevertheless, have its place in the control program, but it alone cannot control the bollworm nor reduce to any appreciable extent the amount of damage it annually causes. Unless other measures are adopted, losses are more than likely to increase over a period of years, depending to some extent upon the acreage under cultivation, crop rotation, etc.

ZEBUS PULLING A DISC AT THE AGRICULTURAL COLLEGE IN VIÇOSA, MINAS GERAES
ALTHOUGH MODERN TRACTORS ARE COMMON IN BRAZIL, OXEN STILL DO MUCH OF THE AGRICULTURAL WORK.

The present status of the pink bollworm in other Brazilian states is nearly identical, particularly where rainfall is plentiful. The exception occurs in the semiarid regions of the northeast where excessive daily temperatures often range as high as 100 degrees F., and where extended periods of drought accompanied by high winds exert much influence on insect survival. Under these conditions, the pink bollworm may be observed over an extensive desert-like region causing a regular amount of loss annually, but never is it very serious except in isolated locations during years of rainfall.

Pectinophora gossypiella has never been known to occur in Peru. This country is one of the few, if not the only one, producing cotton that has not had to contend with the insect, aside from exercising every precaution at port-of-entry to exclude its introduction. Some fear has been expressed that it may gain entrance from Ecuador or over the Andes from the Amazon valley by commercial transport from those regions.

Since the crisis of 1929 agricultural development in São Paulo has made rapid strides towards a more efficient utilization of the soil in the diversification of crops. Up until 1930 the coffee crop represented approximately 70 per cent of the total value of exported products. In 1940 this had fallen to 32 per cent. Cotton became the chief competitor; the total acreage of this commodity was almost equivalent to that of coffee. Corn, rice, beans, cassava, castor beans, and citrus fruits ranked next in their respective order as to acreage. Along with this phenomenal change, industrial output increased and, during the same year, its value was two and one-half times greater than that of agricultural products.

Diversified agriculture has thus become thoroughly established in a land where almost every kind of crop may be grown. Indeed, it would not seem too premature to believe that, along with all the complications involved in a changing agriculture, the part that insects and diseases will play will gradually reach greater proportions as time passes. The cotton plant has long been

known as one of the most attractive of all cultivated plants to insect pests wherever it is grown. In areas where this or any other crop is cultivated on a large scale for the first time, insect pests gradually move in and, if undisturbed, may often become established and in due course of time actually menace the crop. Such is the case of the plant bug, *Horcius nobilellus*, in São Paulo, today ranking among the most destructive cotton pests in the State. Not only do the injurious species take advantage of improved conditions for obtaining food and propagate more rapidly, but so do their natural enemies. Some of these may, after a time, tend to hold certain obnoxious forms in check. The abundance of either the injurious or beneficial forms is greatly affected by seasonal differences in temperature and rainfall. The grower must necessarily experience all these risks and in doing so he soon learns that some insects will cease to be troublesome under certain conditions.

Insect control in the tropics is not as simple as it sometimes appears. Spraying and dusting equipment is expensive and not very durable. In most countries both equipment and insecticides have to be imported. Such products are not always readily available or even accessible to the small producer who seldom cares to invest his meager savings in something he thinks is of doubtful value. Usually the common practice of abandoning a crop in favor of a substitute occurs when insects or other unfavorable factors are causing destruction. If land is cheap and the soil fertile, this method may prove the most economical in the long run. Another practice is to plant more than is necessary on the assumption that a certain percentage will be lost through ravages of one kind or another. Perfectly good farms have been abandoned on account of the leaf-cutting ant, *Atta sexdens,* and related species, because growers either lacked information on their control or found that the expense in combating them was more than they could meet. These ants are native to the tropics, abound in all sorts of locations, and are a constant annoyance to man by attacking many kinds of crops. In Brazil they are considered the most destructive species to agriculture. Even though successful methods have been devised for their control, hundreds of thousands of their colonies will long constitute a veritable menace and require constant attention.

Investigational work on insecticides has not yet received much attention in the majority of entomological institutions largely because there has been no urgent demand for this type of research. As field work on insect biology and control expand, one should expect a corresponding development with insecticides. Possibly the present interest in the production of pyrethrum and rotenone-bearing plants in Latin America will stimulate further interest in this field and encourage the use of new insecticides there.

The application of insecticidal products has been confined almost exclusively to cotton in the form of lead and calcium arsenates and to citrus as oil emulsions. Fumigants, principally carbon disulphide, are used to disinfest coffee and cotton seed and to exterminate leaf-cutting ants. Sulphur and arsenic fumes are employed against ants, and calcium cyanide (hydrocyanic acid gas) is used to some extent against citrus pests and ants. A considerable number of other preparations are on the market, but their use is not very general. Until recently mechanical control of locusts (grasshoppers) had been the most dependable, but not entirely satisfactory, means of controlling these insects in several South American countries. Such methods, however, are rapidly giving way to new discoveries, chief among which has been the application of a dust, containing 3:5-dinitro-o-cresol, by airplane and by hand and power dusters. This development has brought much encouragement to areas where locust plagues occur. Its remarkable success in Argentina should not only prompt its adoption in other South and Central American countries where these insects prevail, but also new possibilities for its application may result against such pests as the Dysdercus cotton stainers and others heretofore not easily controlled.

THE PRINCIPLE OF THE UNOBSERVABLE

By H. M. DADOURIAN

FROM Galileo to Einstein, the physicist went about his researches as if he believed in the principle: *that which is unobservable is not significant.* He did not formulate this principle, however, or consciously make use of it. But because he was looking for observables, he generally avoided unobservables.

Einstein was probably the first physicist to recognize the value of the principle and to use it consciously. He stated it, in connection with the concept of the simultaneity, in the following terms:

> The concept does not exist for the physicist until he has the possibility of discovering whether or not it is fulfilled in an actual case. . . . As long as this requirement is not satisfied, I allow myself to be deceived as a physicist (and of course the same applies if I am not a physicist), when I imagine that I am able to attach a meaning to the statement of simultaneity.

In a very stimulating article, Herbert Dingle points out that this statement of Einstein has been acclaimed as a great discovery by some physicists and philosophers, while it has been condemned as pure nonsense by other physicists and philosophers. Dingle ascribes this divergence of opinion to the fact that the concept of the unobservable has not been analyzed and clearly defined. He analyzes the concept and from it draws some startling conclusions. He classifies unobservables under three heads: the *logically,* the *physically,* and the *practically* unobservable. The logically unobservable is that which violates laws of reason. The physically unobservable is that which cannot be observed by any possible means of observation. The practically unobservable is that which cannot be observed by any known means of observation, but could be observed if these means were refined and perfected to the theoretical limits of their possibilities.

But, according to Dingle, if we assert that something is physically unobservable, while believing in the existence of the external world, we should be assuming that we know all the possible means of observing it. That would be tantamount to presuming omniscience. Dingle concludes, therefore, that we face the dilemma of giving up either the principle of the unobservable or the belief in the external world.

Dingle would retain the principle and give up the belief. For if the principle were abandoned there would be no check to empty speculation and idle invention. As an illustration of what might happen, he says:

> Suppose, for example, I assert that there is a binkum sitting on the table in front of me, and that this tremendous fact, rightly understood, is the final, completely satisfying solution of the problem of evil. If you reject the principle in question, you have no grounds for denying the statement. You may say that you cannot detect my binkum, but I reply that of course you cannot, because he is unobservable. If you want to know how his existence solves the problem of evil, I say that it is its nature to do so, and the definition of him, according to your own contention, is quite independent of any means you adopt to investigate him . . . . Stupid as this example sounds, it contains a precise parallel to the case of simultaneity.

Dingle is thus led to the conclusion that we must give up the belief in the external world and adopt the idealistic view. In the article he does not state what he means by the 'idealistic view.' This he does, however, in his book *Through Science to Philosophy.* His comments on the following quotation from Eddington's *The Nature of the Physical World* shows clearly that his idealistic view is indistinguishable from solipsism:

> The only subject presented to me for study is the content of my consciousness. You are able to communicate to me part of the content of your consciousness which thereby becomes accessible to my own. For reasons which are generally admitted, though I should not like to have to prove that they are conclusive, I grant your consciousness equal status with my own.

Dingle says: "It is clear that there is an inconsistency because other person's consciousness is said to be partly in his own and yet to have equal status with it." Commenting further on Eddington's idealism he continues:

> . . . to say that solipsism is logically irrefutable is to express the fact too mildly. It is not merely irrefutable; it is absolutely true . . . . The real problem is having admitted the necessity of solipsism as a

starting-point, to proceed from it to give a satisfactory interpretation to experience as we know it. . . . He is too honest to obscure the fact that solipsism is the logical starting-point, but instead of starting from it he jumps a gap, for reasons which he would not like to have to prove were conclusive, and sets out with obviously incompatible consciousnesses forced to an impossible equivalence.

It seems to me that both Eddington and Dingle are stating self-contradictory propositions. For if I were a solipsist, you would have existence to me only by virtue of being a part of my consciousness; consequently whatever you communicate to me would be a part of a consciousness which is a part of my consciousness, which makes no sense. Besides, what meaning could I then attach to the word communication?

Whether I grant your consciousness an equal or inferior status with mine, you could not successfully challenge any binkum which I may invent, because the challenge would be from a part of my consciousness to another part. It appears therefore that by adopting solipsism in order to exclude binkums, Dingle opens the door wide to them to come in.

Furthermore, if I proceed from solipsism as a starting-point what would happen? In the process everything external to "myself" would vanish first into nonexistence; then my own body would disappear with the rest of the nonexistent, unreal world; even my past would follow suit. Thus the "real" world would reduce to the momentary "I," the epitome of my consciousness of the present moment. As time passes, the "I" which was real at one moment would merge continuously into the limbo of the vanishing external world, and a new real "I" would appear in its place. Thus, in Minkowski's space-time diagram, there would be only one point-event, the one that represents the ever-present "I."

Therefore if I proceed from solipsism as a starting-point, I finally arrive at the purest stage of solipsism where there are neither observables nor unobservables; consequently the principle which Dingle is rightly anxious to preserve becomes a collection of meaningless words. At that stage science and philosophy, in fact all human activities, lose significance and meaning.

So far the argument stands as follows: Because of its usefulness, the principle of the unobservable should be retained if possible. But if we accept the principle, while believing in the external world, we place ourselves in the untenable position of presuming omniscience. On the other hand, if we renounce the belief in the external world and adopt solipsism, we not only reduce the principle to a meaningless jargon but also get involved in endless logical absurdities.

Dingle has made a real contribution by analyzing the concept of the unobservable, by formulating the principle of the unobservable, and by stressing its importance. But he has drawn unsound conclusions from his analysis as a result of adopting unscientific definitions for the three classes of unobservables. Dingle's dilemma is of his own making and springs from his definitions, as may be shown from a consideration of the following quotation:

Let us suppose that we have discovered all the means of observation that exist in the universe, and know all their properties completely. We might then be able to imagine other means of observation which do not exist. Anything which would be observable by such imaginary means, but not by existing means, would be *physically* unobservable. Anything which would be unobservable by *any* means, existing or imaginable, would be *logically* unobservable. Anything which would be observable by the existing means if we were also omnipotent, but which is actually unobservable because we cannot make full use of the means of observation which exist, would be *practically* unobservable . . . . If we assume that we are omniscient we can distinguish three classes—the *practically*, the *physically* and the *logically* unobservable. If we do not assume that we are omniscient we can distinguish only two classes—the *actually* and the *logically* unobservable, let us call them.

By adopting definitions in terms of omniscience and omnipotence Dingle falls victim to the kind of fallacy involved in dividing two members by infinity and then equating the results to prove that two unequal numbers are equal. These definitions are not scientific definitions in that they do not specify practical criteria by means of which the concepts defined could be distinguished from other concepts. The following definitions are not subject to these criticisms:

Anything is logically unobservable if its definition is incompatible with the laws of logic or necessarily contains logical circularities.

Anything is physically unobservable if its observation calls for means which are incompatible with established facts and principles.

Anything is practically unobservable if its observation calls for means which are not available but which are compatible with established facts and principles.

These definitions enable us to distinguish among the three classes of unobservables without any presumption of omniscience or omnipotence. Thus we avoid Dingle's dilemma of having to give up either the principle of the unobservable or the belief in an external world.

The word 'unobservable' is used here as a scientific technical term. In the ordinary sense of the word it should have no place in the first definition because the question of the validity of a logically unobservable could be determined without resort to observation. In the third definition, it is clear that the 'practically unobservable' is the '*potentially* observable,' which would be a better name for it. Evidently the principle of the unobservable applies only to the first two classes; therefore it may be put in the following more specific form:

That which is logically or physically unobservable is not significant.

Whether a concept belongs to the class of the logically or the physically unobservable may depend on tacit assumptions on the basis of which the concept is defined. This is the case with the concept of simultaneity. The following examples illustrate the application of the principle.

Absolute simultaneity. If we grant the velocity of light to be the greatest velocity of communication, the simultaneity of two distant events becomes logically unobservable because its definition would necessarily involve, as Einstein has shown, the concept of synchronous clocks which in turn would involve the concept of simultaneity; in other words, the definition would contain logical circularity.

On the other hand, if we define simultaneity on the assumption of an infinite velocity of communication, the concept of simultaneity would be logically observable but, according to our definition, it would be physically unobservable because infinite velocity of communication is not compatible with established facts and principles.

The vehement objections raised by the critics of Einstein's statement are partly due to the use of the word 'meaning.' Simultaneity would have a meaning in the ordinary sense of the word on the assumption of an infinite velocity of communication. But it will have no significance until such a velocity of communication is available. Furthermore, the probability of an infinite velocity of communication becoming available is next to nothing, because any communication involves transfer of energy and consequently of mass, and mass moving with infinite velocity requires infinite energy.

Perpetual motion. Perpetual motion of the first type, in which more energy is supposed to be obtained from an engine than is put into it, is logically unobservable because it, in effect, equates two unequal quantities.

Perpetual motion of the second type, in which friction is supposed to be completely eliminated, is physically unobservable because the assumption is not compatible with established facts about friction and physical theories, such as the atomic theory of matter which is based on innumerable facts.

Perpetual motion of the third type, in which all the energy put into an engine is supposed to be recovered as useful work, is also physically unobservable because the assumption is not compatible with established facts and Carnot's principle.

THE GREAT ARYAN MYTH

By KNIGHT DUNLAP

THE Aryan myth is now completely discredited among scholars. Ethnologists (outside of Germany) do not speak of an Aryan race any more than they speak of a Jewish race. Linguists no longer speak of an Aryan family of languages, preferring the less succinct but more accurately descriptive term 'Indo-European.' Popular thought, however, seems still somewhat confused by the word 'Aryan.'

The actual origin of the myth is obscure. Hankins (*The Racial Basis of Civilization*, 1926) traces it back to the early period of the nineteenth century, and if its roots extend further into the past, they are not clearly uncovered. The German warmongers, in the latter part of the century, avidly adopted the myth as dressing for the doctrine sometimes called 'Pan-Germanism': the doctrine of a race of supermen, destined to dominate the world with the ruthlessness of ancient savagery. This doctrine of a great German race, however, is older than the Aryan myth. It was well established before Nietzsche fulminated against morality and humanitarianism. Perhaps the German paranoia can be traced back to Fichte, Schelling, and Hegel, as Hankins implies, and as Kolnai (*The War Against the West,* 1938) seems to think it can be. This possibility is not important for our present purposes. The doctrine of a German race of supermen is certainly older than the Aryan myth.

In its commonest form, the Aryan myth postulated a group of people calling themselves 'Aryans,' who invaded India at some time before the Christian Era and settled in the Indus Valley. Various speculative theories as to the location of the original "home" of these Aryans were invented by scholars who credulously accepted the myth. All the theories agreed, however, that from some place of origin, whether in Europe or Asia, groups of this Aryan stock migrated into India, Iran, and Europe.

If, however, we seek for historical evidence for the existence of this early Aryan stock or for legendary accounts of their migrations and activities, we find that the evidence is nonexistent and that there were no legends about an Aryan racial stock until a century or so ago. The myth is a modern invention.

Many foreign groups have invaded India during the last few thousand years, but there is no reference in Hindu traditions to a group of invading Aryans. There is no reference to such a group in Persian traditions. This is inconvenient for the adherents of the Aryan myth, for although the *Vedas* and the *Avestas* were not written until after the beginning of the Christian Era, they presumably embody legends handed down from earlier periods, or are based on such legends. The word 'Aryan,' and its cognates, appear, it is true, in various writings and inscriptions (see "Aryans," *Encyclop. Brit., Ninth ed.*); but there is no passage or inscription which clearly refers to an Aryan stock or racial group. The word, it is established, means 'noble,' 'illustrious,' or of 'aristocratic lineage.' Only a purblind devotion to a doctrine could twist any of the passages into evidence for an Aryan racial stock.

The myth was the creation of German linguists and philologists, who confused language relationships with racial stock relationships; or who, at least, accepted the former as valid evidence for the latter. We cannot date the origin of the myth earlier than the nineteenth century, because it was not until 1788 that Sir William Jones pointed out that the Greek, Latin, Celtic, French, and Germanic languages had definite affinities with the Sanskrit. In 1808 Friedrich Schlegel declared that Sanskrit was the parent language of the Indo-European group and identified it as the language of a parent Aryan race. Jones' concept of an Indo-European family of related languages was rapidly accepted, and is accepted today, although the 'family' has been rather drastically revised in recent years; but Schlegel's notion that Sanskrit was the original Indo-European language was soon discarded, even by those who gave credence to the myth of an Aryan race.

The myth was developed in Germany during the middle of the nineteenth century by many philologists and literati. Its spread in England and France, and further in America, was greatly promoted by F. Max Müller, a German philologist who became professor of comparative philology in Oxford University. In his lectures before the Royal Institution, in 1861 and 1863, on the *Science of Language* (shortly published under that title) Müller employed the term 'Aryan' for the Indo-European family of languages, and insisted that the various peoples speaking the languages of that family must have had a common ancestry. Somewhat chastened by the critical attacks of anthropologists, archeologists, and the more enlightened philologists, Müller, in 1888, explicitly retracted his doctrine and admitted emphatically that language affinities are not evidence for racial relationships. By this time, however, the impetus which Müller's endorsement had given to the Aryan myth had carried it so far that his retraction could not undo the damage.

Meanwhile, a presentation of the myth which antedated Müller's endorsement had come to the attention of influential Germans. This was the presentation by an obscure Frenchman who had changed his residence to Germany, and who eventually became famous (or infamous) throughout the western world: the Count de Gobineau. De Gobineau had published his *Essai sur l'inégalité des races* in four volumes, in the years 1853–55. In this book he adopted the myth of the ancient Aryan race and attributed superiority to those descendants of the Aryans whose blood was least degraded by mixture with inferior stocks. As to which modern types best represented the original Aryans, de Gobineau seems to have been somewhat uncertain, although he expressed the conviction that the modern Germans are not good representatives and that for the purest descendants of the noble race one would have to look to England where the stock has been better protected by the insularity of Britain.

De Gobineau's *Essai* received little attention for twenty years after its publication, and a second edition did not appear until 1884. The first volume only was eventually translated into English (New York, 1914). In Germany, after the Franco-Prussian War (1870–71), de Gobineau came in contact with Friedrich Nietzsche and Richard Wagner. Nietzsche, the half-Polish proponent of savagery, was apparently much impressed by de Gobineau's ideas; but it was Wagner who gave them publicity through articles in the *Bayreuther Blatter* and brought de Gobineau to the attention of influential persons. Wagner already had the notion of the superiority of the old savage culture of central Europe and its degeneration in modern culture, and was attempting to express this devotion to the dismal past in his music, as Nietzsche did in his pseudophilosophy. Wagner's efforts, it seems, were further stimulated by de Gobineau. Wagner put Gobinism in a conspicuous position, although the *Gobineau Vereinigung* was founded (Leipzic, 1894) after Wagner's death. Houston Stewart Chamberlain, a renegade Englishman, whose writings were influential in France, England, and America in promoting the Aryan myth, was Wagner's disciple and son-in-law.

De Gobineau's suggestion that the English, not the Germans, are the best modern representatives of the Aryans was curiously overlooked or ignored in the spread of Gobinism in Germany. We may surmise (but it is only a surmise) that de Gobineau, after he was taken up by the Germans, soft-pedaled this detail of his theory. At any rate, the doctrine that the Germans are the great Aryans, destined to suppress the decadent humanitarianism represented by Christianity and by ruthless savagery to enslave and rule the non-Aryan nations, became practically the state religion of Germany. This doctrine began to be impressed on the German population very soon, and by 1914 the war lords found it a useful factor in building morale in the first war against civilization. We can understand the avidity with which the warmongers adopted the Aryan myth as an adjunct to Pan-Germanism as well as we can understand Hitler's partiality for the music of Richard Wagner.

The Aryan myth has been relegated to the files of astonishing superstitions, and with it has gone the Max Müllerism (as Reinach called it) which naïvely assumed that language affinities are dependable indexes of

stock relationships. On the other hand, it must not be concluded that the theory that certain patterns of mental abilities and attitudes go with certain racial stocks is now scientifically discredited. Those who assume that there are no mental differences correlated with racial stock differences are speaking from armchairs which are not far from the seats of those who broadcast the claims for the inherent superiority of this race or that. There is no foundation at present for either extreme theory. The problem of racial differences has not been solved; it has not yet even been scientifically approached.

The mixed constitutions of the nations of the world have long been recognized by ethnologists, but in the past, theorists have contrasted the French with the Italians and with the Germans and other national groups, blissfully ignoring the variety of discernibly different stocks entering into the make-up of each of these groups. It is encouraging to note that this sort of blundering does not find a hearing as easily as it did a short generation ago. Our attitudes towards the problems of differences of racial stock are so improved and our delusions so cleared that we may reasonably expect that after this war beginnings will be made on the scientific aspects of the problems.

The delusion that language is an indication of racial relationship was one of the obstacles to the approach to the problems. Another delusion, equally obstructive, was the notion that the form of the head remains constant in a given stock over a long period of time, regardless of environmental conditions. The "holy cephalic index," however, is no longer a sacred symbol to ethnologists. Aside from the *reductio ad absurdum* of the cephalic doctrine subtly given in Dixon's *Racial History of Man* (1923), cumulative evidence concerning changes in the head form in man and in domestic animals moving from one region to another where climate, food, and water are different has shattered the prestige of this symbol and relegated it to the class of growth-characteristics, along with other body proportions which have long been admitted to be unreliable signs of racial stock. The fact that the "goiter regions" of the world (regions in which immigrants from other areas are conspicuously subject to goiter) are also regions in which the peoples long resident are brachycephalic is a significant item in the list of weaknesses of the cephalic theory.

The signs of racial stock which must be employed in scientific studies of the racial problems are those physical characteristics which are least affected by the environment. These signs are eye coloration and hair coloration. A third characteristic which may eventually be of use is that of the skin; but the skin characteristic is complex, and the three factors involved—bleached brightness, rate of darkening (tanning) in the sun, and limits of darkening—are associated in various ways in different individuals and have never been analytically studied. Genetic studies which have confused or ignored these factors have given us no useful information, and the employment of skin characteristics in racial investigations must wait on scientific study of these factors, as well as of the actual color features of skin. Classification of peoples as 'white,' 'brown,' 'yellow,' and 'black' has so far been thoroughly confusing, for some 'whites' become almost black in the sun, while some 'browns' darken very little; and some persons who darken rapidly do not tan as deeply as others who tan more slowly.

Hair colorations blend in mixtures of stocks, giving rise to gradations between red and blond, red and dark brown, and dark brown and blond. Eye colors may blend, but in most cases combine in mosaic patterns which are overlooked in casual observations; the eyes which have greater areas of brown than of blue often being classed as 'blue.' These casual observations gave rise to the popular superstitions, once approved by geneticists, that eye color is inherited in an all-or-none way, with (in the later Mendelian formulation) brown dominant and blue recessive. Few eyes among mixed populations show single colors, but we may infer from the types of mixtures that some "original" stocks were blue-eyed and others brown-eyed, although violet, green, orange, and even red colorations occur in various stocks. It has been commonly assumed that in the skin there is only one pigment, of brownish hue; but the stock significance of the blue "Mongol spot" has not been investigated. As for hair color, we may assume three "original" sorts:

red, blond, and dark brown (often called 'black'), of which the blond is perhaps the most recent in development.

In the European populations various "original" stocks are blended, of which at least five are historically identifiable, although the common names of these stocks are applied in various ways and always need careful definition. These five stocks are: Celtic, Nordic, Mediterranean, Autochthonous, and Mongolian.

The Celts are properly the peoples who were known to the ancient Greeks as *Keltoi* and to the Romans as *Galli* (Gauls). The early Thracians and Achaeans in Europe, and the Phoenecians and other Canaanites in Asia were apparently of the same stock; and groups from Europe settled in Asia Minor (Galatians) in the third century B.C. The Celts were red-haired and blue-eyed, although under the influence of the "holy cephalic index" the name has in modern times been applied to dark-haired peoples residing in the same or adjacent areas. In ancient times these Celts were distributed across central Europe and down into present France (Gaul), but they did not penetrate Britain until about the beginning of the Christian Era.

The Nordics (as we use the term here) were a blond-haired, blue-eyed people known to the Greeks as 'Hyperboreans' and to the Romans as 'Germans'. They were located, when first known, in the Baltic area, although the blond Slavs of eastern Europe were obviously branches of the same stock. The Nordics were people of an extremely savage culture, given to cannibalism and wanton cruelty; but under the influence of the Romans, and later when they were Christianized, they adopted civilized ways.

By 'Mediterraneans' we mean the descendants of the Pelasgi of Herodotus' accounts, who entered the Mediterranean area from the east in prehistoric times and laid the foundation for the civilization which we have inherited. They were modified by mixture with Celtic and autochthonous stocks, but apparently the original type was brunet and brown-eyed. Ethnologists of the nineteenth century confused the Mediterraneans, unfortunately, with the Hamites, who are of a different breed.

The autochthonous peoples of Europe, that is to say, the earliest known inhabitants whose stock still persists, have been given no collective name. The variations in body form and in head form, according to the areas of long residence, are probably responsible for this. The type is brunet of hair, with brown eyes. They were widely distributed in Europe and in the British Isles. Various ancient groups in western and southern Asia were probably the results of eastward movements of this stock.

The autochthones were apparently driven northwards from southeastern Europe by the Mediterraneans and Celts, into the mountains. After the exhaustion of the nations of the Mediterranean area and Asia Minor by the Trojan War, the autochthones seized the opportunity to move down upon the civilized areas of the South. The "Return of the Dorians" was but a sample and symbol of the migration of wild tribes which upset the southern populations, ended the power of Egypt in Asia, extinguished the lingering fragments of civilization in Mesopotamia, and would have extinguished the Ionian civilization of Greece except for its flight for refuge to the shores of Asia Minor. In Greece the Dorians eventually weakened and adopted some features of the culture of the peoples they had enslaved; but the savage invasion was a terrible setback to the growth of civilization.

The term 'Mongol,' 'Mongolian,' or 'Mongoloid' covers a variety of peoples of central and western Asia who have migrated into Europe at various times. The various groups known as Ugrian, Turki, Tatar, Hun, true Mongol, etc., are of uncertain relationship to one another; and the use of the terms above is not intended to be more than the convenient adoption of popular phraseology.

The first mass invasion of Mongolians in historic times was that of the Chazars (Khazars), who moved into the Black Sea region about 500 B.C. and later moved northward and eastward up the great river valleys. They were converted to Judaism en masse about 700 A.D. According to one theory, they have been absorbed into the autochthonous populations, whereas another theory identifies their descendants as the present eastern Jews (the Ashkenasim). There were,

however, groups of savage Asiatics already in the eastern regions of Europe when the Khazars moved in, in addition to Asiatic nomads who had infiltrated the whole Balkan area.

The Bulgars, who gave their name to the Volga (Bulga), were a savage group not distinguished by early modern writers from the Huns, whom they equalled in ferocity, cruelty, and destructiveness. The Magyars, whose stock is still an important factor in the Hungarian population, were originally Asiatic nomads, thought by Keane to have been akin to the Khazars. The early Prussians were a mixture of a Mongolian stock with autochthonous and Slavic stocks. An Asiatic stock called 'Ugrian' (the term is properly the name of a language, not a race) entered Europe in prehistoric times, and their hybridization with Nordics and autochthones produced the Finns, in whom today all three types, or approximations to them, appear.

The second mass invasion of Asiatics in historical times was that of Attila in 445 A.D. The horde of Attila included Mongolians of many types, who are commonly designated as 'Huns.' The Huns penetrated central and southwestern Europe, but their power was crushed in 451 A.D. The horde, however, never withdrew, but remained to mingle their blood with the native populations of central Europe. The German war lords of 1914 appropriately adopted the name 'Huns' as a symbol of the ruthless slaughter and destruction which was, and still is, the ideal of their Aryan doctrines.

Although Attila's Huns were not the last groups of Mongolians to move westward, the hordes of Timur the Lame (Tamerlane) did not reach Europe. They unsettled, however, the already mongolized populations of the Near East and probably accelerated infiltration westward by these peoples. The Turks, who entered Anatolia in the thirteenth century and later and eventually subjugated southeastern Europe, apparently left little of their blood in the European populations.

As far west as central Germany there is an appreciable amount of Mongolian blood in the population. From Hitler's place of origin and from his portraits, we may well surmise that he is of partly mongoloid extraction, although Mussolini may be of straight descent from the old autochthones of the forests. The mongoloid autochthonous element is now in the ascendency in Germany, and the Nordic and Celtic elements are definitely the underdogs. Although, as we have above warned, racial stock may in itself be of no consequence, it is nevertheless true that when a people enthusiastically adopt the ideals of their savage ancestors and attempt to make these ideals actual, their boasted continuity with their savage progenitors is an asset in the building of the immoral morale which contributes to the carrying out of their purposes.

The association of the dominant German group with the Japanese in the present war is curiously appropriate. Although Japan has been under the control of various racial groups since the time of the Ainus, the control at present is in the hands of the Malays, who entered Japan from the south and have gained the ascendency over the older Manchurian element. The place of origin of the Malays is uncertain, but they are classed as 'Southern Mongols.' They have as good claim as the Germans to the name 'Huns,' but we may well assign to both Axis groups the title 'Aryans.' This name has had a foul aroma for fifty years; and since the Germans claim it, and nobody else wants it, we may reasonably assign it to them and their allies, the Japs.

CONVENIENCE AND CONVENTION IN REARING CHILDREN

By LEO KANNER

PARENTHOOD has often been called a task, a job, or a profession. Some writers of popular books on child rearing have set out to prepare parents for this task by telling them what to do in a variety of specific instances, much as a student of chemistry is prepared for laboratory work. If your child refuses to eat, bites his fingernails, or does not obey commands, and you don't know what to do next, you simply look it up in the book and your problem is solved.

There has been no better comment on this attitude than a cartoon which appeared a few years ago on the cover of a widely read magazine. A grim-faced mother, sitting in a chair, has her little boy lying across her lap, bottom up. In her right hand she holds a hairbrush, the immediate purpose of which cannot be mistaken. Her eyes are fixed searchingly on the pages of an opened book which she has in her left hand. What will the book tell her to do?

It would indeed be highly convenient if child rearing were nothing more nor less than a learned job. A famous psychologist wrote not quite twenty years ago in a book which for a time was the bible of literate American mothers: "Many thousands of mothers do not even know that parenthood should be numbered among the professions." Deploring the sad prospect that this profession, "the oldest of the race," was facing failure, he proceeded to instruct mothers when and how they should, or preferably, should not kiss a child, how spankings should be administered and dosed, how a child's bath should be made "a serious but not gloomy occasion." My dear professional mother, aren't we making life comfortable for you? Memorize the rules, and all will be well. Knowing all the rules, you will be able to manage your child as, with the help of a good cookbook, you manage your cuisine. And, by the way, is there any reason why you shouldn't turn your nursery over to a well-instructed governess, as you delegate your kitchen to an efficient cook? You could then enjoy your game of bridge and your other social affairs, with the reassuring knowledge that all the rules are carried out to the dot.

But something must be wrong somewhere. Conscientious, painstakingly punctilious mothers flock daily to physicians' offices and clinics. They have tried to live up to all the instructions read in books and heard from lecturers, yet things don't seem to work out right. Calories and vitamins have been checked carefully, appetizing food has been served in dishes which satisfy all esthetic requirements, and Johnny still fusses over every morsel. Dorothy has been taught the rules of politeness and made to understand the tremendous social importance of saying "Yes, sir," and "Yes, ma'am," but when a visitor arrives, she just stands there, thumb in mouth, and does not utter a sound. Alice has been guarded zealously against any possible source of infection, yet she has more colds than any child in the neighborhood. Bobby has been kept away from every opportunity to hear about ghosts and kidnappers; nevertheless, he wakes almost every night, frightened, and insists on being taken into his mother's bed.

The mothers of Johnny, Dorothy, Alice, and Bobby are puzzled. It is so convenient to know that you have a definite job with definite rules and that you have carried everything out to the letter. Why didn't it work? They want to know wherein they or the instructions have failed.

What is the answer?

The simplest answer is often one that seems remotest. Witness the story of the egg of Columbus. Witness the abstruse "primitive" forms of cosmic orientation in which a multitude of contemporaries is still deeply and militantly immersed.

It took thousands of years for the simple truth to emerge and be accepted by science that genuine parental affection is as much an essential prerequisite of wholesome development as is the need for food and shelter.

Genuine parental affection cannot be learned from books or lectures. It cannot be intellectualized and catalogued into any set of rules of the thou-shalt and thou-shalt-not variety. It is not, as a threadbare slogan has it, the outgrowth of a mythical "maternal instinct." Motherhood is, strange as it seems, not always synonymous with genuine love of children.

Genuine parental affection stems from a combination of fortunate experiences and emotional attitudes. Security, adequately sublimated emancipation from childhood ties, matrimonial happiness, and reasonable freedom from obsessiveness are among the basic ingredients. This combination occurs often enough to produce a majority of fond fathers and mothers whose parenthood is "the real thing" and not a job or profession to be studied in detail. If the real thing is absent, clinical experience shows that even the strictest mechanical adherence to prescribed rules fails to make a child develop wholesomely and happily. If the real thing is there, the parents, whether or not they have read books and listened to talks on child rearing, will satisfy their child's fundamental need for their affection.

Goethe has compressed into one profoundly wise sentence the answer to the quest of many philosophers who, in heavy tomes, tried to account for what makes groping man steer past the numerous obstacles and temptations which life puts in his path: "A good man, though beset by puzzling urges, is always sure to find the proper way." A genuinely fond parent, one who can accept the child warmly and unreservedly, will, like Goethe's "good man," find the proper way, not allowing perplexities to gain the upper hand.

For there will always be perplexities.

It would, of course, be most convenient if a child grew up without ever presenting any kind of "problem," if he always ate as much as his mother wanted him to eat, developed toilet habits at a given age, conformed to tabulated standards of height and weight, and immediately complied with every demand. But, fortunately for the human race, no healthy, sturdy child is perfect in the sense of a wound-up robot who never fails to carry out the functions intended by his originator. A fond parent does not expect this sort of perfection. Minor deviations from precision are regarded good-naturedly and treated with unperturbed resourcefulness; they certainly do not become the source of major parental inconvenience. Such parents are amply rewarded in at least two ways: their affection prevents them from becoming grossly annoyed and angered by the little departures, and their child, thus reared, has no opportunity nor need for really disturbing rebellion or withdrawal.

But to a mother who does not fully and wholeheartedly accept her child, these departures, which are a part of the process of growing up, present a personal affront, a sin which the child commits against her as a parent. Her orientation is that of a punitive, retaliating authoritarian. When she brings her child to the clinic, her complaint takes the shape of hostile accusation. She expects the physician to do something—she does not know what—to the child to make him more acceptable to her or to tell her in so many words how she should remodel the child whom she cannot accept as he is.

Of course, the realization of hostile feelings toward one's offspring, condemned by society as unnatural and reprehensible, would be even more inconvenient and unacceptable than the child himself. The rejecting parent needs a face-saving "reason" for the rejection outside his or her own emotional condition. There must be something within the child which makes him objectionable.

Ethnologists tell us of whole communities which could not tolerate differences from the ordinary course of development. There were savage tribes that exposed or killed infants whose upper incisors erupted before the lower ones. This change of sequence, which to us appears innocuous enough, was viewed as evidence that the baby harbored within him the wrath of demons who must be appeased by the victim's death.

Our own conventions, our own traditional ways of thinking have discarded the demons quite some time ago. Even the spells and curses, superstitiously believed to produce illness and misconduct, have been relegated to small, unenlightened areas hidden from the paths of modern civilization. The ire of supernatural beings can no longer serve as justification for rejecting a child; it had to

be replaced by something more in harmony with current conventions.

Ours is a scientific age. The advances of science are transmitted to the public in the form of manifold new technical devices and, by way of schools, printing press, and radio, through simplified explanations of the basic concepts underlying the inventions and discoveries. On the whole, the popularizers of science are doing a grand job. It is not their fault that many people, even among the psychometrically intelligent, cannot rid themselves of the age-old need for mysticism and magic. This need has brought about a new type of superstition, which is perhaps best characterized as pseudoscience.

Pseudoscience offers to rejecting parents the emotional comfort which they must have if they are not to suffer severely from the full awareness of their attitude. Beneath, they feel guilty enough but, for the sake of self-esteem, cannot allow the feelings of guilt to come bluntly to the surface: Pseudoscience provides welcome relief, mostly in the guise of pseudogenetics and pseudomedicine.

If a child misbehaves, it would be most inconvenient to recognize in his misbehavior a reaction to lack of parental affection and acceptance. The cause must be within the child. Scientists speak of constitution and heredity. These concepts are often taken over by the laity as ready-made interpretations of any physical anomaly or deviation from postulated norms of conduct. We are, after all, barely one generation removed from the time when a highly arched palate, an adherent earlobe, and a Darwinian tubercle were considered as "stigmata of degeneration," evidencing inherent "predisposition" to villainy and prostitution. Even today there is still considerable controversy in scientific circles about certain grossly and repetitiously nonconforming people whose inaccessibility to reforming efforts is referred to a preordained congenital quality, spoken of as constitutional psychopathic inferiority.

What greater comfort is there than the assumption, derived from pseudogenetic wisdom, that a child's "nervousness," or "stubbornness," far from reflecting parental attitudes, can be traced to some kind of predestined "remote control"? The hunt for a skeleton in the family closet is hardly ever unproductive; at least some collateral antecedent can be found, usually a black sheep, who in his early years had demeaned himself "just the way Johnny does." Johnny, patterned by heredity, can therefore not be accepted as he is; he must be made over lest he grow up to be as bad as the ancestor after whom vicious Nature has contrived to mold him.

If heredity does not oblige, the child's body gets the blame. There are countless pseudomedical notions to chose from. A sick organ exculpates not only the parent but also the child. It is convenient to be able to feel: I am a good parent, and I have a good child; it is a physical illness which causes him to misbehave.

A college graduate mother, insecure, unable to emancipate herself from dependence on her own parents, resenting her husband's failure to walk through life as a replica of her father, encountered great difficulty with her baby son. During her pregnancy, she had made an unsuccessful attempt at aborting him, soothing her conscience with the conviction that she would not be capable economically of giving her child "all the advantages"; her lawyer husband had a nice income, and they had a spacious home and adequate domestic help. When Dickie arrived, she atoned for her efforts to prevent his coming by thrusting all her energies upon him. Child rearing, to her, was a succession of rituals which must be followed to perfection. She was anxious that her child be well-nourished; her parents "liked them plump." She overfed him and when he refused excess food, she started on a regime of forced feeding. Dickie responded with refusal of almost all food. She recalled that her grandmother had died of gastric cancer, had heard that cancer is hereditary, and concluded that Dickie's "lack of appetite" resulted from a "shrunken stomach." Certain that this was a first symptom of the dreaded disease, she took Dickie to many doctors but could not be calmed by their reassurances. The doctors, she suspected, were just trying to keep the bad news from her. Dickie, sent to a convalescent home, offered no problem there and ate splendidly. On his return home, the misery started all over again. His mother decided to seek psychiatric assistance. She

had an opportunity to vent her own emotional involvements. As she did so, she came to see gradually how her entanglements had influenced her relationship with Dickie. She was able to reshuffle her attitudes, and the relationship improved step by step. She no longer needed her grandmother's cancer and the child's "shrunken stomach" to bolster her up. Dickie, now fully accepted by a much more secure mother, no longer needed the resort to the shenanigans which had plagued her. He developed wholesomely and is now a well-functioning high school student.

The difficulty usually comes out into the open when the biologically helpless, and therefore, submissive, "baby" becomes a willing person and his will begins to assert itself by refusing to remain a passive tool of parental domination. It is perhaps for this reason that, in so many complaint statements, the word willfullness is used as a synonym for stubbornness and obstinacy. There are parents who find the emergence of the will inconvenient and upsetting. They cannot accept it for what it is—a natural and desirable acquisition in the evolution of personality. "Will," which finds expression in the presence of alternatives, is deprived from the start of the guided opportunity to choose between alternatives. Nothing except compliance with the parent's will is tolerated. Any show of initiative and spontaneity which does not strictly conform to parental demands is bewailed as "disobedience" and raises the issue of "discipline." And discipline, to such people, means a lesson in unquestioning, uncritical, unconditional surrender.

Disciplinarianism as a basis for child rearing is made respectable by traditional convention. The rod has, since biblical days, functioned as a symbol of prophylaxis against spoiling. Children who are seen and not heard are still extolled by some as the ideal products of child rearing. Bending of the twig is still often recommended in a way which takes little precaution against overbending or even breaking. Habit training is often interpreted as agitated habit enforcement.

The conventional concept of discipline comes as a godsend to rejecting parents. It sanctions and, in fact, prescribes parental autocracy. If the child does not capitulate—and no healthy child does—his remonstrance, in spite of all the seeming inconveniences which it entails, serves as a welcome justification for an attitude of nonacceptance: "How can I be satisfied with a child who does not obey, refuses his cereal, does not empty his bowel at the exact time when I want it emptied, and throws a temper tantrum when I insist? Such a child is 'bad,' and I am entitled to a 'good' child. His badness must be inherited or the result of some physical illness." This is how the resort to pseudogenetics and pseudomedicine fits into the picture.

Psychologists have recognized children's early remonstrance as a normal phenomenon of growth. Some have spoken of a "period of resistance" in the second and third years of life as a natural stage of psychological development. There was a tendency to ascribe this resistance to attributes contained in the anlage; a predisposition to transitory negativism was supposed to be dormant in the newborn, as the milk teeth are hidden in the jaws, to appear in the course of infancy, and to give way to conformity, as the milk teeth give way to permanent teeth. Clinical studies, however, show clearly that the pointing to chromosomal origins disregards something much more real and more readily demonstrable. It shows that so-called resistance is nothing more nor less than a first exercise in choosing between available alternatives, a first attempt at self-assertion. Since the choice cannot, and does not, always coincide with parental expectations, the instances of divergence tend to impress impatient parents as evidences of resistance.

The degree of resistance depends largely on the extent to which force is used in trying to obtain compliance. Force creates an atmosphere of hostility. A child, finding himself surrounded by disapproving autocrats, has the choice between allowing himself to be crushed and fighting back. Most children have enough stamina to fight back. They discover that their refusals are powerful, and the only, weapons at their disposal. "Discipline" acts as a boomerang. The parents, frustrated and offended, meet resistance with counterresistance, and a vicious circle is established. The child and the

parents are contestants in constant warfare. They get "on each other's nerves." The less genuine affection there is for the child, the lower is the threshold of parental annoyance.

Not long ago at a social gathering, the mother of two boys who are now serving overseas in the Armed Forces reported how delighted she used to be when in years past her sons came down on Sunday mornings, sprawled out on the living room carpet and read the funny papers. A short time afterwards, another mother brought her 7-year-old boy to our clinic. She insisted that Tommy was very bad. One of the examples of his badness was his habit of coming down on Sunday morning, sprawling out on the living room carpet, and reading the funny papers. It was the same behavior in both instances. To the fond parent, it gave pleasure and a pleasant memory. The rejecting mother, whose threshold of annoyance was very low indeed, was irked by it and saw in it one more "reason" for her accusing attitude. The two soldier sons had a secure, happy childhood. They had no need for behavioral backfiring. Tommy was a crushed child, in danger of giving up and withdrawing, but still, luckily, possessed enough vitality to continue his struggle, which would have been hopeless without intensive psychiatric assistance.

The nuisance value of a child's behavior, determined by parental emotional attitudes, derives in no small degree from cultural, "conventional" factors. Hardly a better example can be found than that of thumb sucking. For centuries babies were allowed to indulge to their hearts' desire. Medieval artists depicted angels with thumbs in their mouths to give them the appearance of heavenly bliss. Toward the end of the past century, thumb sucking suddenly became a "behavior problem," an "undesirable habit." Parents were told that the thumb introduces pathogenic germs into the oral cavity, that the habit will result in dental malocclusion, and that—so it was decreed in the early days of psychoanalysis—it indicated a "constitutional re-enforcement of the erogenous significance of the lip zone." The author of a widely circulated book on child care warned that mothers who let their children suck their thumbs "are condemned in progressive communities." Commercial killjoys flooded the market with bitter stuffs to be smeared on the offending fingers, thumb guards, modified strait jackets and Elizabethan collars, and other torture instruments. Anxious mothers, who do not wish to be condemned, get up several times in the night to jerk thumbs out of children's mouths.

It is truly amazing how many inconveniences some parents can take upon themselves for the sake of the convenient feeling that their mode of child rearing is directed toward the prevention of future calamity. Behind it all is a disconcerting lack of faith in a child's ability to develop his potentialities without being constantly jerked and forced by agitated adults.

We live in a thoroughly pessimistic age. The grand idea of prevention, one of the greatest medical advances, is linked much too often with gloomy anticipation of disaster. Devils are painted on the wall, and inkwells are thrown at them. Parents who lack genuine affection for their children and genuine faith in them consider themselves under obligation to "prevent" a child from being malnourished by cramming food down his throat, from being infected by keeping him isolated from other children, from having low marks in school by standing over him when he does his homework. Every slightest behavior item which does not measure up to the conventional ideal is viewed with alarm as a one-way ticket to doom and must therefore be forcibly eradicated. A parent, so oriented, is forever occupied with the child. Thus, paradoxical as it may seem, a rejecting parent often becomes an oversolicitous, overprotective, "spoiling" parent. It is such comfort to be able to say: "Of course, I love my child. Behold! I am sacrificing every minute to his welfare. I deny myself many pleasures because I must devote myself to him. I read books and articles on child rearing and follow all the rules. Alas! I am ill rewarded. He does not appreciate my efforts. He is a difficult and ungrateful child."

Such mother love is not "the real thing." It is smother love. The child's rebellion is the only avenue left open to him if he is not to be smothered. It is a normal reaction to

an abnormal situation. The parent sees in it only an invitation to redouble the smothering, to regard the child and his conduct as abnormal, and to want him to be remodeled. The common accusation is: "He is making a nervous wreck of me," or: "He always keeps me on the run."

These attitudes of open or disguised hostility are not the outcome of premeditation. Many parents would be profoundly unhappy if they "knew" that they had such feelings. Freddie's mother, referred to the clinic by the family physician, did not have the slightest realization of her deep hatred of her affection-starved son when she hurled against the psychiatrist what seemed to her the most devastatingly incriminating charge: "Why, you *like* Freddie!"

These attitudes are not the results of intended viciousness. They are indications of emotional difficulties within the parent. Emotional difficulties cannot be remedied by logic, argument, or prescription of rules. They certainly are not helped by social conventions which take sides for or against a child or a parent.

Next to home relationships, school life is the most incisive experience in a child's development. There are many teachers who are fully aware of this and introduce richness and warmth into the classroom. A child who is nagged at home finds himself accepted at school. His secure relationship with the teacher helps him to modify the impression, gained at home, that living means constant looking out for, and getting back at, adult critics and punishers.

But there are also teachers whose own emotional difficulties make them intolerant and autocratic. Their ideal of convenience is a classroom full of little Lord Fauntleroys. Their low threshold of annoyance makes a culprit of every pupil who does not conform to this ideal. Children who are loved and happy at home will usually manage to remain unscathed by schoolmarmitis. But a child who has been made suspicious or rebellious by domestic censure is apt to respond to the teacher's perfectionism as he has learned to respond to parental obsessiveness. His responses, because of their nuisance value, are criticized severely. Home and school close in on him. Parent and teacher sit in judgment over him and find him wanting. His world does not accept him and builds into him a foundation of unhappiness and hostility.

The twentieth century has been called the century of the child. Infant mortality has been reduced. Child health has been improved. The specialty of pediatrics has made tremendous progress. Schooling is accessible to every child in the country. Child guidance clinics are available in many communities. Child labor laws afford protection against economic exploitation.

The century is now in its fifth decade. The world is engulfed in a life-and-death struggle for the rights of man. Man starts out in life as a child. The rights of children include the satisfaction of the fundamental human needs for affection, acceptance, and security. Parent education will have to emphasize these needs. Instead of laying down rigid rules of child rearing, the people who do the educating must help parents, singly and in groups, to be aware of children's rights to growth, spontaneity, and self-expression and to foster them as fond guides and not as carping censors. False notions of convenience must be dispelled. Conventional attitudes must be brought into being which give social approval to genuine parental affection and recognize children's "behavior problems" as safety valves and calls for help rather than nuisances to be suppressed dictatorially.

Then, indeed, will the twentieth century live on in the history of mankind as the century of the child.

SECONDARY EDUCATION IN BRITAIN

By T. D. A. COCKERELL

IT may be said of the British that they have two main objectives: the first, to win the war; the second, to make a Better Britain, which in its turn will be instrumental in creating a Better World. Some say, first win the war and then talk about those other aims. But this is surely a mistake, even from the point of view of winning the war. The battle is being waged for the future, and what we do today will affect the country for many centuries to come. It is the sense of this responsibility to the future which inspires the fighters of today; without such hope and faith they might well be discouraged.

Thus the war has helped to clarify the public mind and to develop a patriotism based rather on the future than on the past. People know, or think they know, where they are going, what they are aiming at. Perfection, whether in the individual or in society, is impossible, but we may strive toward it and attain a large measure of success. As we move forward, new vistas will appear; we shall always be on the road, never at the journey's end.

In this striving it is evident that problems of education must take a foremost place. This is recognized in Britain, and even in the midst of war a bill is being passed by Parliament designed to greatly enlarge and improve educational opportunities for all the people. However, very much has been done in recent years—more than most people realize. I was born in England in 1866 and came to the United States first when about twenty years old. I am thus in a position to compare the past of more than half a century ago with the present, and in several respects the progress has been noteworthy:

(1) The old classical curriculum, with its emphasis on Latin and Greek, has given way to a much broader one in which natural science, including biology, has a prominent place.

(2) The secondary schools for girls are now very numerous. Some schools are coeducational, as is customary in America, but many are for one sex, and those for girls are very active and enthusiastic, judging from reports received.

(3) The old grammar school has expanded to include pupils up to seventeen and eighteen years of age, taking them right up to university entrance.

(4) The traditional divisions of society are breaking down, largely under the influence of the schools, and we may expect to see the children of nearly all the citizens in school together, as has long been the case in the United States.

(5) More attention is paid to the status and qualifications of teachers. I observe that the headmasters and headmistresses of all the schools from which I have letters have university degrees. Dr. C. Foster tells me that the teaching staffs are nearly all graduates.

Recently, my wife developed a plan for reprinting my zoology textbook, published by the World Book Company and used in connection with my lectures at the University of Colorado, and sending a thousand copies to the British Board of Education. It was her idea, and I confess that I regarded it with some measure of doubt. I wondered whether a book coming from America would be welcomed and whether it would be used in the schools. However, we heard from Mr. Butler's Department that it would be acceptable, and now that the books have been distributed to secondary schools all over England and Wales, it appears that the gift was made just at the right time and that there was absolutely no prejudice against it on account of its American origin. I refer to this in order to explain how it happened that we received over 280 letters from the various schools, frequently giving very interesting details about their work, their history, or their experiences in the war. From these letters and from some printed sources, especially H. C. Dent's *Education in Transition* (London, 1944), we get an interesting picture of British secondary education at the present time. The impression gained is one of great activity and enthusiasm, but perhaps it is more favorable than the entire

situation justifies, the letters coming from the ablest and most active teachers. In any case, there is great interest in education throughout the country, and it is apparently realized that the Better Britain will be due more to education than legislation, or rather, legislation cannot be very effective unless supported by education.

In order to understand the present position of the schools, it must be remembered that many of them date from very early days and cherish traditions inherited from the past. Mr. S. W. Whitehouse, headmaster of the Alsop High School for Boys at Liverpool, writes: "I began my teaching career at Worcester Cathedral King's School, which was founded in 680 A.D., and about the year 1000 had a saint as its headmaster!" Another school was founded about fifty years before Shakespeare was born; another during his lifetime. The "ffree Grammar Schole of Newport" was founded in 1588 through a bequest from Mrs. Joyce Frankland. The circumstances connected with the founding of this school are dramatic. Mrs. Frankland had only one child, a son, who had finished his course at Cambridge and entered as a law student at Grays Inn. On August 22, 1581, he was riding an unbroken and spirited horse and was thrown and killed. Alexander Nowell, Dean of St. Paul's, being a close friend of Mrs. Frankland, hastened to her and later told this story of his visit:

> The mother fell into sorrowes uncomfortable, whereof I, being of her acquaintance, having intelligence, did with all speede ride to her house near Hoddendon to comfort her the best I could, and I found her cryenge or rather howlinge continually, O my sonne, my sonne! And when I could by no comfortable words stay her from that cry and tearing of her hair, God, I think, put me in minde at the last to say, 'Comfort yourself, good Mrs. Frankland, and I will tell you how you shall have twenty good sonnes to comfort you in these your sorrowes which you take for this one sonne.'

Mrs. Frankland never referred to this advice during the nearly six years she lived after it was given, but in her will left money, as Dean Nowell had recommended, to found scholarships and fellowships at Oxford and Cambridge and to establish a free school for about fifty scholars at Newport in the county of Essex. "For the love I bear to learning and to have youth well brought up and instructed with fear of God, learning and good manners, whereby they may be good members of the Commonwealth."

In 1851 rules were adopted for the guidance of the school. The subjects to be taught were "Writing, Reading, Arithmetic, and Elementary Mathematics, together with Good Manners and all other instruction and learning fit to be taught in a Grammar School." The pupils were between the ages of 8 and 14.

The Hulme Grammar School at Oldham, Lancashire, was endowed in 1606, in the reign of James I, and began to function in 1611 with about thirty pupils. The curriculum was English, Latin, Greek and Good Manners. It seems to have been the case with all or most of these ancient schools that however limited the curriculum, it included and emphasized "good manners."

The Hulme School is now a very active and forward-looking institution and is greatly interested in good will between Britain and the United States. I have a pamphlet giving an account of the Founder's Day Service, February 27, 1942. It is an admirable example of the spirit of the best modern schools, derived from the feelings and thoughts of the teachers and scholars, not from anything imposed from without. The service begins with the Processional with four verses, of which I quote two:

> The changeful years unresting
> Their silent course have sped,
> New comrades ever bringing
> In comrades steps to tread;
> And some are long forgotten,
> Long spent their hopes and fears;
> Safe rest they in thy keeping,
> Who changest not with years.
>
> They reap not where they labored,
> We reap what they have sown;
> Our harvest may be garnered
> By ages yet unknown—
> The days of old have dowered us
> With gifts beyond all praise;
> Our Father, make us faithful
> To serve the coming days.

I cannot imagine that anyone could hear these words without strong emotion. After the sermon, by a Chaplain to the Merchant Navy, they sang as the Recessional "The Battle Hymn of the Republic." This was followed by "The Star-Spangled Banner"

and the British National Anthem, ending with:

> Kinsfolk in love and birth,
> From utmost ends of earth,
> God save us all!
> Bid strife and hatred cease,
> Bid hope and joy increase,
> Spread universal peace,
> God save us all!

Enclosed with this came a sheet "The True Hulmeian," a Credo written by an Old Hulmeian serving with the Royal Navy, at sea, October, 1942:

> I believe in the dignity of hard work, whether with the head or hand, that the world owes no man a living, but that it owes every man an opportunity to make a living.
>
> And in the supreme worth of the individual.
>
> I believe that every right implies a responsibility; every opportunity an obligation; every possession, a duty.
>
> And that the rendering of useful service is the common duty of mankind.
>
> I believe that truth and justice are fundamental to an enduring social order.
>
> And that the law was made for man and not man for the law; that government is the servant of the people and not their master.
>
> I believe in the sacredness of a promise; that a man's word should be as good as his bond; and that character—not power, or position or wealth—is the true test of human values.
>
> And that thrift is essential to well-ordered living and that a reasoned economy is a prime requisite of sound structure, whether in personal, business or government affairs.
>
> I believe in an Almighty and an All-Wise God, named by whatever name, and that the individual's noblest fulfilment is to be found in high ethical integrity and self-discipline.
>
> And that Right can and will inevitably triumph over Might.

In such ways have the ancient schools developed, and it is not surprising that they are jealous of any domination from above or interference with their customs or ideals. A Canadian teacher once gave me an example of blind bureaucracy, which, he said, greatly irritated the teachers in the schools. The Inspector came around and found the teachers marking the absences from class. "This will not do," he said. "You must instead mark those who are present." This is an extreme case, but it shows what is possible. But so far as I can learn, the Board of Education in Britain has a very elastic policy, permitting wide diversity, but requiring the schools, if they are to get a grant in aid, to do well what they profess to do. This applies equally to the Catholic schools, from which I have received very cordial letters.

In America we have heard complaints of the domination of the secondary schools by the universities, but we must agree that the prospect of continuing education affords a valuable stimulus. In my early days we had the University Matriculation Examinations, given all over the British Empire. The same papers were sent to London and were read by examiners who made this their regular occupation. In this way any high school, no matter where it might be, could be compared with others, and a certain uniformity of teaching resulted. This standardization was no doubt beneficial in many ways, but we used sometimes to wonder whether it did not go too far, inhibiting originality and special adaptation to local conditions.

The only criticism I received about my zoology text was, in a very few letters, a question whether the topics, or the manner of their treatment, might not quite suit the examiners. There is, of course, a strong tendency for a body of professional examiners to develop fixed ideas, not in keeping with the progress of science. We like to think that we are teaching Truth, but if Truth is Reality made manifest, we must recognize that new truths are constantly emerging, modifying our previous opinions. This contrasts strongly with the dogmas of religion, and to some people seems to suggest the futility of science. But we must progress and, while teaching and acting according to our best understanding, look forward to constantly increasing wisdom in the future.

The education of women in Britain has gone forward to an astonishing degree in recent years. I recall very clearly when women who sought university education were ridiculed and called "blue-stockings." Gilbert and Sullivan wrote a play to hold them up to scorn. When Cambridge established a girls' college (Girton), it was placed far from the town to avoid contaminating influences. But later a second college (Newnham) was placed in the midst of Cambridge. Visiting Newnham College, I saw in the great hall a large painting of a man in academic costume.

"Who is that?" I asked.

"He was undergardener here."

"But how could that be?"

"Well, he was Professor Sedgwick, a famous professor in the University, but his wife was Mistress of Newnham. He naturally desired to live with his wife, but there was a statute to the effect that no man might sleep in the College except a few servants whose duties were specified. So the professor received the appointment of under-gardener."

Thus were the girls guarded. One is reminded a little of the comment made by a Mohammedan we met in the Orient. Said he: "We value our women and keep them shut up where they are safe and screened from the vulgar gaze. You treat your women as if they were of no account and let them rattle about the world." And, indeed, in recent years women have been exploring the most remote countries without male escort and coming to no harm.

Miss Winifred Appleton of the Northgate School for Girls at Ipswich sends me interesting details about the education of girls. There was mention of a girls' school as early as 1709, but in 1737 the Directors of the school passed the following resolution:

> Whereas the girls have for some years past been taught to write at considerable expense, without the order of the Governors, it is now ordered that no girls henceforth be taught to write at the expense of the Society.

Ninety years passed before girls were put on something like an equality with boys. A minute of July, 1826, provides for "writing and ciphering for girls during the last two years, and a female assistant to be appointed to teach same."

Erasmus Darwin, the grandfather of Charles Darwin, quoted by Charles Foster (*School Science Review,* December, 1939), made the following suggestions concerning the education of girls in 1797:

> Besides the acquisition of grammar, languages, and common arithmetic, and besides a knowledge of geography, and history, and natural history, there are other sciences, an outline of which might be taught to young ladies of the classes of the school or of more inquiring minds, before or after they leave school, which might not only afford them present amusement, but might enable them at any future time to prosecute any of them further, if inclination and opportunity should coincide; and, by enlarging their sphere of taste and knowledge, would occasion them to be interested in the conversation of a greater number and of more ingenious men, and to interest them by their own conversation in return.

But I recall that, in my young days, it was considered bad manners to discuss any technical or scientific subject with a woman, as she, being ignorant, would be placed in a humiliating position.

Today, the very numerous and very modern schools for girls take them up to university entrance, and many enter the universities or colleges. Thus, for instance, the large girls' school at Luton, Bedfordshire, reports that many of the girls are looking forward to careers in medicine, teaching, agriculture, and nursing. The County School for Girls at Penzance, Cornwall, reports that they have nearly three hundred pupils and that they "prepare them for the School and Higher Certificates of the University of Oxford. Many of them go into banks and offices when they leave school, but a good proportion go on to universities and ultimately go in for secondary teaching, the Higher Civil Service, or medicine. Many become teachers in elementary schools after two years' training at a training college, and a number go in for nursing." At the High School at Newark-on-Trent the girls not only prepare for the university, but also for a variety of professions of social importance in the community. So it goes in many schools, and it is evident that a new era for women is opening up. The reforms in teaching and medicine now being initiated will call for great numbers of teachers and doctors, and many of these will be women. Whatever may be the present attitude of the government, there can be little doubt that before very long the pay and opportunities for women will be similar to those for men.

When I was a boy in a private school at Beckenham in Kent, the nearest approach to science we had was half an hour of geography once a week. The teaching of science in the schools came slowly, and the tradition was that real erudition was largely confined to a knowledge of the classics. We recall a satire of those days directed to the attitude of the learned:

> I am Benjamin Jowett—
> Master of Baliol College;
> Whatever is known, I know it,
> And what I don't know isn't knowledge.

It must be said for such men that they were not only classical scholars, but culti-

vated gentlemen, worthy members of their communities. The ancient culture was well defined, whereas the science of the day was largely amorphous, not too certain of itself. Indeed, this difficulty will not be overcome; the adherent of a static system of knowledge or philosophy has a certain advantage over one whose subject is in a continual state of flux, always progressing and being more or less made over. It is only when we have accepted the view that progress is the normal condition of mankind, just as it is the normal ambition of the individual, that we can escape from the old systems of fixed ideas. And so escaping, we encounter hazards, and know very well that we are sure to make mistakes.

Dr. Charles Foster (*Annals of Science*, July, 1937) quotes Dr. George Birkbeck on the origin of the Mechanics' Institutes at the end of the eighteenth century:

> I resolved to offer a gratuitous course of elementary philosophical lectures. When the plan was matured it was mentioned to some of the wise in their generation. They treated it as the dream of youthful enthusiasm, and scarcely condescended to bestow upon it a sneer, for it appeared to them so thoroughly visionary and absurd. They predicted that if invited the mechanics would not come; and if they would come they would not listen; and if they did listen they would not understand. The offer, however, was made. They came, they listened, they conquered; conquered that prejudice which would have consigned them to the domination of interminable ignorance, and would have shut the gates of knowledge against a large and intelligent portion of mankind forever.

In the early nineteenth century, the teaching of scientific subjects, initiated by the Mechanics Institutes, spread to the schools, but slowly. Foster says the recognized teaching of science in secondary schools dates probably from about 1870. In the meantime, public lectures and "Penny Readings" were popular and served to convey to the people much information not offered in the schools.

Science teaching in the past has emphasized physics and chemistry rather than biology. This tendency has naturally been stimulated in later times by the many important discoveries and inventions resulting from work in these fields. I notice in recent discussions supporting scientific work that almost the whole emphasis is often placed on the production of material wealth. No one, today, would deny the value of this work, even though, through the wickedness of man, it has in part had such lamentable results. But more should be said in favor of biological studies, which, as in medicine and agriculture, have given results which lengthen life and bid fair to abolish poverty, while at the same time have great cultural value. It seems that this is coming to be realized in the British schools. I find that the many letters received nearly all refer to some biological work being done. Dr. C. Foster of Buckingham writes:

> There has been a great development in the teaching of biology during the past ten years. Not many schools are large enough to give specialized teaching in biology to a very high standard as yet although that is what we are mostly trying to do. The great majority of schools have now adopted schemes for the teaching of "General Science," in place of the old physics and/or chemistry, and, in this, biology takes quite an important place. Thus nearly all secondary schools give some kind of biological teaching.

With regard to the cultural value of biology, we have long had many amateur naturalists—entomologists, conchologists, botanists, ornithologists, and so forth. These groups have greatly enjoyed their work and stimulated good fellowship between many who would not otherwise have come together. An important factor has been the production of small, well-illustrated books on different aspects of natural history, and another influence has been that of the local museums. There are magazines devoted to the natural history of particular regions. Some of these amateurs have become professionals or specialists, but on the amateur level there is much for the public good. England is surely one of the most beautiful countries in the world, with truly remarkable fauna and flora. Thus the English patriot thinks of those things, as well as of the people and the buildings and the history of other times. It is an important part of education to emphasize these things and bring them to the attention of the pupils. I like the attitude of Miss Jeanne Harrison of the School for Girls at Penzance, Cornwall:

> The school is a granite building on a hill on the outskirts of Penzance and overlooking St. Michael's Mount and the bay. It has a most beautiful position. When I first came here last May I could hardly

believe it was real, it was so beautiful. From my study window I can see the sea and the Mount, and on certain days it looks just like a fairy castle. The other day the base of the rock was shrouded in mist and from it the castle rose, looking quite phantom-like. On other days the sea is a brilliant turquoise bluey-green, and when the sun is shining on it, it looks more like a Mediterranean scene than one in England.

I have never been in Cornwall, but I recall the very handsome slugs a correspondent sent me from there. And the sea of that region is full of marvels, as all biologists know. After all, are not these the things which help to make the good life, without which all material benefits are likely to be sterile?

Many letters tell of the destruction during the blitz, but fortunately it occurred principally at night when the children were not at school. The following from Miss E. M. Curry of the Aigburth Vale High School, Liverpool, is characteristic:

This school was badly damaged in the blitz, and though we did not lose our main library, we had a good deal of damage to books and equipment. The central hall was burnt out by incendiary bombs, and a little later bombs "straddled" the building, but only knocked down the front gates! Then after that, a bomb destroyed a temporary accommodation we were using, and twice windows were damaged by blasts! So you see we suffered a good deal, but there was no loss of life. All one winter we worked in the building with no roof over the central hall, so we sometimes thought it quite warm when we got the temperature of the Form Rooms to 45 degrees F.! But all this was three years ago, and now we are a school of over 500 girls, which is the biggest the school has ever been.

All of which seems to throw light on the saying, "There will always be an England."

For a detailed discussion of recent educational developments in England, we can strongly recommend H. C. Dent's *Education in Transition*, published in January, 1944. It ends as follows:

The difficulties ahead are great and numerous. But they are not insuperable. Given courage, clarity of mind, a common purpose and a common inspiration, we can master circumstances, we can eliminate vested interests, we can conquer apathy, we can cure ignorance, we can bring the true light of life to all. And, having achieved the revolution, we may confidently expect that

a loftier race
Than ere the world has known shall rise,
With flame of freedom in their souls
And light of knowledge in their eyes.

That is the purpose of education in a democratic society.

TO CELLS

All life about an anatomic frame
Of jellied flesh and centered nucleus
Expands its theme from chromosomal dust
To cloistered mite unique in every claim:
Mitotic marvel splitting genes in play,
Cyclotic, enzymatic, vibrant ball,
As gland, as nerve, contractor serving all,
A trophic evocator or a living clay.

Is life explained in terms of sums of these?
Are we the psyche of unnumbered hosts
High sovereign while they live? Can no one tell?
Belief, distrusting logic, seeks the soul's release
From planless worlds. Has each live thing its ghost
Or shall we find the psyche in each cell?

—John G. Sinclair

SCIENCE ON THE MARCH

PHOTOSYNTHESIS OR PHOTOSYNTHESES?

PHOTOSYNTHESIS is the process in which sugars are synthesized from carbon dioxide and water in the green parts of plants when they are exposed to sunlight. The quantity of sugar made by terrestrial plants in this process has been estimated at 6×10^{13} kilograms per year. The essential biological significance of photosynthesis, however, does not lie in the enormous quantitative output of sugar, but in the fact that the existence of the entire biological world of plants and animals, with negligible exceptions, hinges upon this process.

From a few simple inorganic compounds and from the sugar made in photosynthesis are built up the multitude of complex kinds of molecules which constitute the bodies of plants and animals or which are otherwise essential to their existence. Some of these subsequent syntheses occur in the plant body; others in the bodies of animals after they have ingested plant materials as foods.

The energy used by plants and animals also stems from the process of photosynthesis. The carbon dioxide and water used by green plants in the synthesis of sugar contain no releasable energy, but the sugar does. The energy in the sugar molecules, releasable upon oxidation in the cells of plants and animals, represents energy of sunlight entrapped during the photosynthetic process. The entire organic world runs by the gradual expenditure of the energy capital accumulated during photosynthesis. From the narrower viewpoint of purely human welfare photosynthesis is the ultimate source of all our food, all of our fuel, and of many of the raw materials used in industry.

Photosynthesis is dependent upon the presence of certain pigments in plants. The actual seat of the process, except in a few very simple plants, is the chloroplasts—small spheroidal bodies which occur by the hundreds in most of the cells of leaves and in many other kinds of plant cells. The chloroplasts of all higher plants contain two very similar pigments—chlorophyll *a* and chlorophyll *b*—which impart to leaves and landscapes their distinctive green color. Also present in the chloroplasts of higher plants are carotene and certain xanthophylls, all yellow pigments. The presence of these pigments is masked by the darker-hued chlorophylls. The chlorophylls are known to be necessary for the occurrence of photosynthesis, and the yellow pigments may also be essential for this process.

All the above-mentioned pigments appear to be present in the chloroplasts of all higher plants—mosses, ferns, and seed plants—although the exact proportions among them are not the same from species to species or even from plant to plant within the same species. The situation is different, however, in the heterogeneous group of plants commonly lumped together as "algae." Various investigations, mostly recent, indicate that the chloroplast pigment systems differ from phylum to phylum among the algae and in most algae are different from the system found in the higher plants. Only in the green algae (*Chlorophyceae*), the group which includes many of the fresh water "pond scums," does the pigment system appear to be the same as that in the higher plants. All the higher plants and algae do, however, appear to have two pigments in common, chlorophyll *a* and carotene.

Brown algae (*Phaeophyceae*), the group to which most of the larger "seaweeds" belong, especially those indigenous to the colder oceans, contain chlorophyll *c* (chlorofucin) instead of chlorophyll *b*. These plants also contain a number of xanthophylls, most of which are not found in higher plants. These include fucoxanthin, the brown pigment which masks the presence of chlorophyll and imparts to brown algae their distinctive color.

The microscopic diatoms (*Bacillariophyceae*), grass of the oceans, accomplish a far larger proportion of the earth's photosynthesis than is generally realized. According to the most conservative estimates, the aggre-

gate yearly photosynthesis of marine plants, mostly diatoms, is at least twice that of terrestial plants, an estimate of which has been given above. Like the brown algae, these plants contain chlorophyll *c* instead of chlorophyll *b*. The xanthophylls present are different from those in higher plants; some, including fucoxanthin, are identical with those found in the brown algae. Diatoms are brownish or yellowish because the quantities of xanthophylls present are sufficient to obscure the presence of the chlorophyll.

The group of red algae (*Rhodophyceae*) includes most of the smaller "seaweeds," especially in the warmer oceans. These plants contain neither the chlorophyll *b* of green algae and the higher plants nor the chlorophyll *c* of the brown algae and diatoms, but chlorophyll *d*, which seems to be restricted to plants of this group. Xanthophylls are either lacking or else are present in exceedingly small quantities. The predominantly red color of plants of this group results from the presence of the pigment phycoerythrin.

Yellow green algae (*Xanthophyceae*), a group resembling the green algae, are distinctive in that they appear to contain only the *a* variety of chlorophyll. The xanthophylls of these plants also appear to be different from those of other kinds of algae.

The examples given are sufficient to illustrate the point, although they do not exhaust the possibilities. Several other groups of algae, each with a more or less distinctive pigment complement, have not even been mentioned. It is highly probable that additional chlorophylls and xanthophylls will be discovered in the photosynthetic tissues of plants.

The existence of different chloroplast pigment systems in the algae of different groups suggests that the photosynthetic mechanism may not be identical in all kinds of algae. The mechanism of photosynthesis, like the pigment system, appears to be the same in all the higher plants and in the green algae. Practically nothing is known of the actual mechanism of photosynthesis in algae of other phyla. However, some algae, notably the diatoms and yellow green algae, unlike other green plants, accumulate considerable quantities of oil in their cells. Petroleum deposits, in fact, are commonly supposed to have resulted from the physiological activities of diatoms of past geological eras. Whether or not the accumulation of oil in the cells of diatoms is a direct consequence of some distinctive feature of their photosynthetic mechanism is not known, but it is a suggestive fact in connection with the known pigmentation differences among algae.

That the mechanism of photosynthesis is not identical in all plants has already been shown on a limited scale. In the purple sulphur bacteria, a little-known group of organisms, occurrence of photosynthesis does not result in any release of oxygen into the environment as it does, so far as is known, in all other photosynthetic organisms. These plants contain only one kind of chlorophyll which is of a different variety from that known for any other kind of plant. They also contain certain yellow pigments.

Extensive investigation of nature's different versions of the photosynthetic process will not only contribute to the broadening of scientific knowledge, but may make more direct contributions to human welfare. It has long been a dream of scientists to be able to capture the sun's energy directly, without the intermediation of the green plant. The best possibility of by-passing the green plant in the acquisition of radiant energy is by means of some purely physical photochemical reaction, more or less analogous to photosynthesis. The more we know about the chemical mechanics of the photosynthetic processes of plants, the structure of the molecules of the pigments involved, and the kinds of products formed, the more likely it is that some day we shall be sufficiently fortified with knowledge to realize this goal.—B. S. MEYER.

BOOK REVIEWS

THE PSYCHOLOGY OF WOMEN

The Psychology of Women. Helene Deutsch. xiv + 399 pp. $4.50. 1944. Grune and Stratton.

THIS is a psychoanalytic interpretation of the psychology of women from their early years to maturity, by a psychoanalyst of considerable experience who has made woman her special study. A second volume will deal with the psychology of adult womanhood.

The book will be of particular interest to teachers, parents and, of course, psychologists, for Dr. Deutsch manages to throw much light on many obscure problems connected with woman, of whom it has been correctly stated that "age cannot wither her, nor custom stale her infinite variety." Many readers will find in the pages of this book much with which they will be unable to agree, and they may find its style somewhat arid, but they will carry away with them some new insights into the psychology of women. Heyman's *Psychologie der Frauen* (not mentioned in the present work) was a much more readable book and very informative, even though it was published over thirty years ago, but it was written from a more formal psychological standpoint.

On the whole this book may be recommended as an original and stimulating contribution to our understanding of woman. We look forward with interest to the publication of the second volume.—M. F. ASHLEY MONTAGU.

THE AMERICAN NEGRO

Characteristics of the American Negro. Edited by Otto Klineberg. 409 pp. 1944. $4.00. Harper and Brothers.

IN this volume there have been brought together a number of the monographs prepared in connection with the *Study of the Negro in America* under the direction of Dr. Gunnar Myrdal and the sponsorship of the Carnegie Corporation of New York. In a sense, therefore, this volume is a sort of omnibus for rather generally-connected studies: "The Stereotype of the American Negro" by Guy B. Johnson; "Tests of Negro Intelligence" and "Experimental Studies of Negro Personality" by Otto Klineberg; "Race Attitudes" by Eugene L. Horowitz; "The Hybrid and the Problem of Miscegenation" by Louis Wirth and Herbert Goldhamer; "Mental Disease among American Negroes: a Statistical Analysis" by Benjamin Malzberg. As one reads the volume, one is struck by an inherent tendency of the subject matter to overlap and a more serious conflict of terminology, especially with reference to the use of *race* and *racial,* and the frequent substitution of these terms by *ethnic, national, caste,* and similar terms. Since the personality of the American Negro is vitally affected by how he is racially defined, it seems imperative that scholars agree on this definition, its biological basis, and its social interpretation.

The presentation of the stereotype of the American Negro is itself a stereotype: quotes from various printed media, scientific and unscientific, which delineate more or less popular concepts of the Negro and Negro-White relationships. Johnson himself observes that evaluation of such a method of assessment is far from satisfactory; it is subjective, personal, and leads to no really sound concept of Negro personality and culture traits. Klineberg offers more objective material in the form of scores and ratings based on various performance tests. Klineberg presents some new material, but for the most part his two contributions are based on his book "Race Differences." The tabulation of calculated scores, arranged in a hierarchical rating, highest to lowest, pays obeisance to performance rather than innate ability or potentiality. In other words, there is far more a mere measure of achievement level rather than an analysis of educational opportunity—or the lack of it!

The section on attitudes by Horowitz contains much original material, though it leans heavily on Lasker, Moreno, Minard, and Crisswell. Then, too, this section seems to integrate more clearly with the theme of the entire volume, for in discussing the inception of race attitudes it regards personality as a biosocial complex that must take cognizance of race not only as a biological classificatory product, but one which is molded by, and

molds, social reactions as well. Horowitz reaffirms the familiosocial basis of race attitudes (really race prejudices) during the early grade school years. In a sense Wirth and Goldhamer extend the biosocial theme in their study of miscegenation as they analyze the social problems engendered by the biological process of Negro-White intermixture. They are not concerned so much with the genetics of such crossing as with emergent cultural patterns and problems, and as a result chapters on provenience, intermarriage, passing, and personal characteristics of hybrids are more adequately treated than the chapter on physical characteristics of hybrids. But this fact does not detract from the all-around value of their contribution: the hybrid emerges as a distinct social entity and a potent cultural force.

Malzberg statistically affirms what Klineberg has earlier implied, viz., that the mental test differences that do exist between peoples are not biological, i.e., not neuromuscularly innate, but socially conditioned.

The volume is a welcome and a real contribution to our knowledge and understanding of the American Negro. Read it and read it carefully: you'll find that intolerance and prejudice are overcome before a steady and logical march of facts and interpretations.—W. M. KROGMAN.

REHABILITATION

Principles and Practice of Rehabilitation. John Eisele Davis. 211 pp. 1943. $3.00. A. S. Barnes and Co.

NOWADAYS, at every turn in medical literature, in lay journals, and in the daily press, one finds the word "rehabilitation" freely used. That this is true is a healthy sign, for it means an interest in the disabled, whether of war or peace, and in their restoration to useful lives, even though this prodigal use of the term inevitably means a broadening of its connotation, with a corresponding decrease of its denotation.

Most people, when they speak the word, think of the physically disabled — the maimed, the deaf, the blind. To limit the use of the term to designate these groups is erroneous; it is equally wrong to apply the word *only* to those suffering from mental disorders. This latter is precisely what Dr. Davis does, and to that extent his title is misleading. The subject matter, however, is entirely sound, as we should expect from so experienced and careful a worker in the field of recreational and occupational therapy as applied to psychiatric problems. Dr. Davis' work at the Veterans Facility at Perry Point, Maryland, has long been outstanding.

The chapter headings are: Effect of War and Depression; Psychiatric Approach (brief discussion of the main clinical entities); Psychological Approach (largely a presentation of some tests, but omitting mention of Doll, Wechsler, Rorschach or Murray); Interest and Effort Theories; Elementary Principles of Mental, Nervous and Physical Reconstruction; Modern Methods; Therapeutic Objectives and Results; Handicraft, Education and Art. There are numerous helpful charts and diagrams, most of them devised by the author. There are also numerous illustrative case histories.

Dr. Davis is an eminently practical man, and his chapters on practice are the best. He is a leader in his field, and his volume is a useful contribution to the literature. Everyone interested in the psychological aspects of rehabilitation should read it.—WINFRED OVERHOLSER.

MANKIND SO FAR

Mankind So Far. William Howells. Illus. xii + 319 pp. 1944. $4.50. Doubleday, Doran and Co., Inc.

THERE is a rapidly mounting curiosity among Americans at the moment regarding the peoples of other parts of the world. Not only has the war made us more aware of distant races of mankind, but it has confused us on the very concept of race. Dr. Howells' book, with its perspective on mankind, thus comes at an opportune time.

This book is directed at the general reader and does not presuppose a college course in zoology; it starts by explaining the vertebrates and carries their evolutionary classification from fish through amphibians, reptiles, and the lower mammals to the Primate Order. The anthropoid apes then receive fairly detailed consideration and finally man himself—in his fossil, recent, and future forms—is dealt with in the last two-thirds of the volume. By picturing man in this broad zoological setting in such a way as to

attract a wide audience, Dr. Howells has had to devote considerable space to lower forms and consequently curtail his description of man—even to the point of omitting contemporary distributions. Many readers who have been attracted to this subject by current events will be disappointed by this omission and more so by the lack of a bibliography to aid them in further search for this information.

Considered within the limitations of its scope, however, Dr. Howells' book is well written. Technical expressions are cleverly avoided or explained without giving the reader the impression of being "talked down to." As a sparkling example, ischial callosities are described as:

> . . . a tongue-twisting euphemism for those two gay and shining patches of bare, tough skin in that region described by Mr. Westbrook Pegler as the sole of the pants. A mandrill, therefore, gives you bright greeting whether he is coming or going; reversing the day, his face, red, purple and blue, recalls the sunset, while his departing presence imitates the dawn.

If there is any criticism of such an interesting style of writing, it is perhaps that scientific concepts are not always made entirely clear. Thus, on the first page it is stated that man's ". . . organization and all his parts go back, lock, stock and barrel, to the anthropoids . . ." Now many readers will know of the contemporary apes as the anthropoids and so will be confused by the use of this term synonymously for fossil and modern forms. In this connection they may be startled when they get further along by the statement that ". . . the gorilla's likenesses to man do not necessarily signify that man descended from him."

Other examples of this style, which perhaps emphasize contradictions because of the lack of context, are the following: "Evolution is a fact, like digestion." "It is like saying that you are descended from Charlemagne; it can't be proved, but there is, nevertheless, little doubt of it, considering his family life." "Man used [brachiation] also, while he was an ape, but on becoming a man he suddenly specialized intensely . . . His uprightness is unique. . . ." "The great mark of the apes is that they are invariably upright in posture."

Actually, such minor faults may be more apparent to specialists than to general readers and probably are of small consequence when compared with the great mass of facts and interpretations accurately and interestingly presented. The summary and analysis of the fossil human record in particular are quite comprehensive. Indeed, the good features of this book predominate and make it both a useful and worthy member of the American Museum of Natural History Scientific Series.—T. D. Stewart.

THE PACIFIC

The Pacific World. Edited by Fairfield Osborn. Illus. 218 pp. 1944. $3.00. W. W. Norton & Co.

Pacific Ocean Handbook. Eliot G. Mears. Illus. 192 pp. 1944. $1.00. James Ladd Delkin, Stanford University.

If war has any benefits at all, one of them certainly is the stimulus it gives to the increase and dissemination of human knowledge in various fields, and in the present "global war" geographical knowledge has benefited outstandingly. One wonders sometimes, however, what our soldiers, sailors, and marines themselves think of the dozens of handbooks, aids, guides, and manuals that are prepared for their edification, and whether the military prosecution of the war might not sadly suffer if they took time to read them all. Be that as it may, many excellent and useful works have lately appeared, those listed above being two of the most recent additions to the "handbook" literature of the Pacific region.

Mr. Osborn's book, sponsored by the American Committee for International Wild Life Protection, is a compilation designed to give a general picture of the entire Pacific, "its vast distances, its lands and life upon them, and its people." In so small a book, covering so great a territory, there is room for only the barest exposition and description. Beginning with an introduction by the ubiquitous William Beebe, addressed to men of the armed services, the book proceeds through twenty chapters, the first eleven dealing with the general geography, discovery and exploration, climate, astronomy, the native peoples, and the natural history; the last nine with regional descriptions of Australia and New Zealand, Melanesia, the Netherlands Indies, the Philippines, Micro-

nesia, Polynesia, Japan, the Aleutians, and other island groups. The book is simply and clearly written, with an obvious effort to appeal to the so-called popular reader. If the book gives the impression of being too sketchy for other than elementary usefulness, it may be explained that a series of supplemental handbooks is being prepared by the same Committee. The numerous charts and maps are especially helpful, for in their preparation graphic illustration rather than adornment has been paramount. The illustrations were executed by Robert M. Chapin, Jr., Andrey Avinoff, Francis Lee Jaques, Joy Flinsch Buba, and Charles Clark. The misspelling of Mr. Jaques's surname is so frequently perpetrated by publishers that it is no surprise to find it again misspelled here both on the title-page and jacket. As our favorite poet once wrote:

> What good is happiness, or health, or fame,
> If only one in ten can spell your name?

Whereas "The Pacific World" stresses the anthropology and natural history of the region, since the sponsoring Committee believed "that literature regarding the animal life of the Pacific islands would encourage its conservation," the Mears volume is written from a more purely physical-geographical approach, Professor Mears himself being a geographer of considerable reputation and an authority on ocean currents. It is a handbook in both size and content—compact and factual—with no other aim than to provide the reader, be he soldier or civilian, with essential facts in the most convenient form. It tends strictly to business and wastes no words. It is not written for the technical expert and at the same time does not write down to too low a level. The neophyte seeking knowledge will find here a wealth of data on all main and peripheral matters pertaining to the Pacific—the Pacific Basin, Oceania, volcanoes and earthquakes, tides, currents, winds, storms, precipitation, fog, navigation, and geomagnetism, to list a few. A dozen appendices provide quick tabular information on such subjects as area and population, standard time, distances, wind scales, sea food for the shipwrecked, weights and measures and currency, chronology, monsoons, coral islands and reefs. All these help to make this book a sort of World Almanac of the Pacific—*multum in parvo.* The illustrations, though small, serve their purpose reasonably well, and for the second edition illustrations have been added and many of the maps and charts have been redrawn and clarified and in some cases enlarged. We understand that the publisher of this handbook has not been able to get enough paper allotted to him to meet the demand of sales. We could, if pressed, suggest considerable current printed matter that might be done without, if it would mean that meritorious publications such as "Pacific Ocean Handbook" could get enough paper to carry on.—Paul H. Oehser.

MAN DOES NOT STAND ALONE

Man Does Not Stand Alone. A. Cressy Morrison. 107 pp. 1944. $1.25. Fleming H. Revell.

The subject matter of this little book is an attempt to consider objectively some of the scientific evidence bearing on the existence in the universe of a Supreme Intelligence. Evidence is presented and elaborated on the postulate that the existing known phenomena pertaining to nature and to mankind and their relationships would be impossible without the existence also of Supreme Intelligence and without the existence likewise of definite purpose in the universe. According to the author, such definite purpose is the preparation of the soul of man for immortality. Numerous interesting facts have been assembled, organized and presented, and equally interesting conclusions have been derived therefrom. The subjects of some of the chapters are self-explanatory: our unique world, atmosphere and ocean, the gases we breathe, nitrogen, what is life?, how life began, origin of man, animal instincts, the development of mind, genes, the world's greatest laboratory, checks and balances, and time. The scope of this notice, however, does not include detailed synopses of the various ramifications of the author's discussion, nor do space limitations here permit of quotations therefrom of sufficient length adequately to illustrate his charm as a writer or the breadth and profundity of his thought.

Although the book should not be considered as being controversial in character, its

title has been selected as a challenge to the conclusions given in a recently published work, written by Julian Huxley, entitled "Man Stands Alone." The author of "Man Does Not Stand Alone" is a past president of the New York Academy of Sciences and of the American Institute of the City of New York; member of the executive board of the National Research Council; fellow of the American Museum of Natural History, and life member of the Royal Institution of Great Britain.—J. S. WADE.

INDEX FOSSILS

Index Fossils of North America. Hervey W. Shimer and Robert R. Shrock. Illus. 837 pp. 1944. $20.00. Massachusetts Institute of Technology Press.

THIS excellent book, designated as a revision of Grabau and Shimer's "North American Index Fossils" published in 1915, because of its scope and wealth of new material embodying the results of research and publication up to Pearl Harbor, so far surpasses the latter that it might well be considered a new book. The 534 pages of text contain descriptions of approximately 2,500 genera and 7,500 species of invertebrates and a few plants, excellent bibliographies of the larger divisions, an index of genera, and one of species. The 303 full page plates contain over 9,400 illustrations of the described species. In addition to the discussions of all major groups of invertebrate fossils, there is a short section on fossil plants and miscellaneous probable fossils which are often encountered by the invertebrate paleontologist.

This should be a "must" book in the library of every American paleontologist. It can well be used as a reference for lecture and laboratory work in courses in invertebrate paleontology and stratigraphy as well as a general reference for all paleontologists and stratigraphers. It is so important that it really deserves review only after one has had time to study and make use of it for teaching and other purposes.

The primary purpose of the book, which has been well attained, is to describe and illustrate as many as possible of the fossils which can be used to identify, date, and correlate formations. No doubt many persons will feel that certain species which they have found useful should have been included. However, it would be impossible in a book of this size to describe and figure all fossil forms which can serve this purpose, and the selections which have been made, even if they do not include all known index fossils, represent the considered opinions of the persons who have selected them

The book is largely the work of the authors, but many of the sections have been prepared or revised by workers who are specialists on particular groups of fossil forms. Practically all of the large divisions of the text were examined by one or more specialists and many of the smaller divisions are largely the work of other specialists who have given freely of their knowledge. This careful preparation and revision gives to the work merit and authenticity which it otherwise could not have. Due acknowledgments for all contributions in the form of text, illustrations, or other information are completely made.

Sections prepared by colleagues of the authors are as follows: Foraminifera by Joseph A. Cushman, Lloyd G. Henbest, and W. Storrs Cole; Crinoidea by Raymond C. Moore and Lowell R. Laudon; Conodonts by Edwin B. Branson and Maurice G. Mehl; Brachiopoda by G. Arthur Cooper; Insecta by Frank M. Carpenter; Charophyta by Raymond E. Peck; and Calcareous Algae by J. Harlan Johnson. Larger sections revised by specialists are: Blastoidea by Lewis M. Cline, and Paleozoic Gastropoda by J. Brookes Knight, with the collaboration of Josiah Bridge and R. R. Shrock.

The book begins with an introductory chapter in which the authors explain the purpose of the work, the nature and method of presentation of the contents, the sources from which descriptive and illustrative material were obtained, and the extent of contributions and revisions by others. This is followed by definitions of various terms which are used in the text, such as index fossils, form species, form genus, and different types of index fossils.

The introductory chapter is followed by ten others, each of which deals with a major division of invertebrate life, usually a phylum. Chapter 12 treats of fossil plants and miscellaneous objects of probable or-

ganic origin. The order of treatment of the various phyla is arbitrary and was chosen for practical reasons. Description of genera and species of each group of organisms is preceded by a discussion of general characters of the group. These discussions are of varying length depending upon the different authors. In general, however, they are brief because the user of the book is assumed to have a general knowledge of invertebrate paleontology or to have available suitable textbooks from which such information may be obtained.

Genera and species are described according to a definite plan except where some other method is more appropriate. Genera are usually described in taxonomic order, the divisions having the oldest fossil representation first. In a few cases where satisfactory taxonomic grouping has not been made, such as for the Trilobita, the genera have been arranged alphabetically for major time divisions. Species are considered in stratigraphic order, oldest first. Rules of the Committee on International Zoological Nomenclature have been followed faithfully and every effort has been made to insure the proper generic name, author, date, and genotype. Generic and specific descriptions are necessarily condensed but include the most characteristic and diagnostic features. Geologic range and geographic occurrence are given.

Some innovations in taxonomy have been made. Three of the more noteworthy of these are worth mentioning. The Conularidae which in the past have been assigned to various biologic groups, but most commonly to the Mollusca, are herein classed as Scyphozoa. Classification of the Brachiopoda used in this book differs from the generally accepted practice. Two classes, Inarticulata and Articulata, with the two commonly recognized orders, Atremata and Neotremata of the Inarticulata and the order Paleotremata of the Articulata are recognized. Instead of orders Protremata and Telotremata, the remainder of the brachiopods are classified into Impunctate Articulata, Pseudopunctate Articulata, and Punctate Articulata. Although the last three units are not called orders, they are treated essentially as such. Certain small Crustacea, *Agnostus* and related forms, which formerly were classed with the Trilobita, are placed in a separate subclass, Agnostia.

Illustrations have been obtained from various publications, new photographic prints of published figures, new photographs of specimens previously illustrated in published reports, and original and unpublished photographs and drawings. In spite of these different sources the plates are uniformly good, many of them excellent. The plates of line drawings in the section on crinoids are especially valuable to show plate structure.

Adverse criticisms are few. One discrepancy between description and illustrations caught the writer's attention. The trilobite genus *Pagetia* is described as possessing three thoracic segments, yet illustrations of the two described species show only two. There are surprisingly few orthographic errors for a book this size, and these may be typographic. The printing is good with only occasional incomplete or blurred letters. The abundant usage of bold faced and italicized type is especially helpful in emphasizing important matter.

In summation, this book is a work well done. There is no other comparable book in existence. The authors and their colleagues deserve unstinted praise for producing such a splendid volume under the difficult conditions of the past three years. Especially commendable is the waiving of all royalty rights by Dr. Grabau, senior author of the first edition and A. G. Seiler, publisher of "North American Index Fossils," and the assignment of all royalties by Drs. Shimer and Schrock to the Technology Press to help defray the cost of publication. This is truly an example of the scientific spirit.—A. H. SUTTON.

COMMENTS AND CRITICISMS

ON "SCIENCE AND THE SUPERNATURAL"

My Son, these maxims make a rule,
An' lump them ay thegither;
The Rigid Righteous is a fool,
The Rigid Wise anither:
The cleanest corn that e'er was dight
May hae some pyles o' caff in;
So ne'er a fellow-creature slight
For random fits o' daffin.

—Robert Burns

The following letters are expressions of opinion on A. J. Carlson's lecture, "Science and the Supernatural," which was republished in the August issue of the Monthly. The first of these letters was addressed to Dr. Carlson; the others, to us. We have asked an eminent scientist to submit an article on the same subject, expressing a different point of view. At the moment we can only add to the letters here quoted some profound and beautiful thoughts (in italics) of great writers of the past.—Eds.

If you will accept a word of appreciation from a member of our A. A. A. S.—a retired Quaker business man holding only a modest degree in Science but a deep interest in scientific progress—I would like to thank you for the privilege of reading your William Vaughan Moody Lecture, as reprinted in the Monthly of August.

My pleasure in following the beautifully stated and elaborated points of your dialectic, and sense of very general unity with it, has suggested to me the possible propriety of my writing you with reference to one point upon which I would have greatly enjoyed a fuller expression of your views than you apparently felt warranted in offering. I refer to your brief mention of alleged objective evidence for personal immortality and, in particular, to your suggestion that communications with the dead by clairvoyance, "psychic mediums," and "ectoplasm," may scarcely be dignified as evidence; and that when examined, the "ectoplasm" appears to "go the way of all errors and frauds." You simply comment, rather briefly, that you "know these attempts," and are "still skeptical."

This may seem but a trifling point in the wide sweep of your argument, but I would have welcomed the privilege of learning what you know of these attempts to produce evidence of personal immortality, and your reasons for being "still skeptical." For I have given the subject of evidential value of survival phenomena some years' intensive study, and have come to conclusions that tend to vary somewhat from your own conclusions, if I correctly understand your conclusions to be that such alleged phenomena do not afford reliable evidence.

I do not suggest, for a moment, that the knowledge which I have obtained in this field can bear comparison with your own. I am only wondering how it is, that the 90-year series of investigations by distinguished scientists such as Hare, Crookes, Flammarion and Lodge which I have reviewed; the great number of individual cases I have studied; the several hundred books that I have read; the living investigators whom I have consulted; the score or more of reputable psychical mediums with whom I have held some hundreds of "sittings"; and the easy and evidently quite natural psychical communication with the "dead" which we have been able to develop and maintain in our own family circle—how it is that all these items of experience can build up, as they unquestionably do, into a single consistent picture of evident reality, without there being, in fact, any reality there.

You had, no doubt, personally covered such a minimum program of inquiry as mine, and gone far beyond it, before you felt warranted in expressing yourself as you did. But, as you see, it is not altogether clear to me how you could have done so, and come out at the end, "still skeptical." The vast accumulation of items, wholly consistent with one another, which constitutes the "weight of evidence" for any theory, whether in the physical or physiological field, is here present as undeniably as it was in the case, for example, of Harvey's theory of the circulation of the blood, or Copernicus' astronomical theory, or Mendeleeff's theory of the periodicity of the elements. Is it inevitable that the same prejudice which they encountered on the part of academic opinion, is likewise to plague a soundly based and fully authenticated theory of personal immortality?

I feel that such a body as our American Association is bound to be at a disadvantage with respect to its position on this subject, until it has made that position clearer than your brief comment, as President, makes it. I wish that I might place a small fund in your hands, and ask you to appoint someone to prepare a summary of objective and subjective evidence for personal immortality, as ninety years of experiment and experience have produced it. I think that I could assist such an appointee to obtain a wide measure of able and helpful collaboration.—S. Rowland Morgan.

There is nothing strictly immortal, but immortality.—Sir Thomas Browne.

I want to compliment you on your vision in reprinting Carlson's "Science and the Supernatural" in the August, 1944, number of THE SCIENTIFIC MONTHLY. There is an urgent need today for a much wider diffusion of Carlson's clear-cut thinking on this supernatural question.

I wish that Carlson's article might be reprinted and placed in the hands of every high school teacher in this country.—SAMUEL S. WYER.

Your article "Science and the Supernatural" by our one-track-physiological-minded President, A. J. Carlson, is an insult to the intelligence of members of the AAAS.

Carlson neglects the first and most fundamental principles of science, exactness in definitions and thoroughness in research.

If the editorial staff is so exacting in their science publications, what may be your excuse for resurrecting an article which lacks all the earmarks of scholarship?—D. W. MILHONE.

Believing as I do that man in the distant future will be a far more perfect creature than he now is, it is an intolerable thought that he and all other sentient beings are doomed to complete annihilation after such long-continued slow progress. To those who fully admit the immortality of the human soul, the destruction of our world does not appear so dreadful.—CHARLES DARWIN.

I wish to express my appreciation of the article entitled "Science and the Supernatural" by Dr. A. J. Carlson, which appears in THE SCIENTIFIC MONTHLY for August, 1944.

It seems to me that during the last two or three decades there have been all too few such clear expressions of opinion on this important subject as that given by Dr. Carlson in this article, which I note was first published in 1931. In the days of Huxley and his contemporaries such expressions of conviction were rather common, but since that time only occasionally has such an article appeared in an outstanding scientific magazine.

I am a very religious individual, but I am of the opinion that such articles as this do a great deal of good. Considering how large a proportion of human thought and emotions are concerned with the supernatural, it would seem to me that scientific literature might well devote more attention to it.

I hope that before long you will be able to publish another article on the same topic, by some scientist as eminent as Dr. Carlson, but taking some other point of view. Preferably the author should be a physiologist or biologist, because I note that Dr. Carlson is slightly suspicious of other types of scientists. I take it that his observations about the physicists, in the second column on page 94, were occasioned by some articles expressing a different point of view from his, which were appearing at about the time when he originally wrote this address.

I am sure that many others among your readers must have enjoyed, as I did, Dr. Carlson's excellent use of language, the clarity of his thinking, and the person to person attitude in which he expresses his convictions. I have never heard him speak, but at the end of the article I had a feeling as if I had been sitting in the hall listening to his lecture. It is true that he seems at times to offer as statements of fact what are merely expressions of opinion, and also that apparently he regards science as the only path to truth . . . which, of course, might even be so, or might not. But I found the article very inspiring reading, and cannot refrain from expressing my opinion that it, and other articles like it, make real contributions to human progress.—JAMES WATSON, M.D.

Is it the function of THE SCIENTIFIC MONTHLY to "front-page," as it were, sneering attacks on religion by eminent scientists? President Carlson has as much right to his opinion on these matters as anyone else, and as much right to defend those opinions, provided it is done in a rational rather than an emotional way, and with due respect for those of equal competence with himself who differ from him. But these saving characteristics are entirely lacking in the lecture which you reprint as the opener in the current issue of the MONTHLY. The address is a continuous succession of contemptuous slurs on religion. These come to a climax when the author condescendingly remarks: "the modern man of science has no essential quarrels with Jesus, ... They did the best they could, considering the ignorance of their times." Such a comment comes with a profound shock to the devout Christian reader, whether scientist or non-scientist. Has Dr. Carlson no respect for such of his fellow-scientists as Robert A. Millikan, Sir Arthur Eddington, Sir James Jeans, and many others, who are devout Christians as well as scientists, as conversant with scientific method as himself? It would have been far better if you had allowed this lecture to continue to gather dust in the files of *Science,* where it originally appeared, rather than to resurrect it in the pages of the MONTHLY. I hope very much you will ask some equally reputable scientist who does have some use for religion to present the other side of this question, in language more temperate than that of President Carlson. If I had the time I would be much tempted to do this myself at length, but I am afraid no science-proud scientist would pay much attention to the raving of a mere philosopher! And certainly, no professional theologian should enter the lists. But I am quite sincere in my expression of concern.—JARED S. MOORE.

If I err in my belief that the souls of men are immortal, I gladly err, nor do I wish this error, in which I find delight, to be wrested from me.—CICERO.

In reprinting "Science and the Supernatural" you have done the greatest service to all members and indirectly to all Americans.

For more than twenty years I have been reading the Monthly and I believe I have never written you before, but Dr. Carlson's article is so important I feel I must commend you for it.—HARRISON HIRES.

Some men of science show a regrettable tendency to comment adversely on the foundations of Christian Faith. Such questions lie without the scope of physical science, and no scientist known to me has contributed to our knowledge of the subject.

Without having polled them, I suspect that most teachers of science and those doing laboratory work for industry are Christians. But whether they are or not has no relation to their skill and achievements in scientific development. Study of physics and chemistry and biology and astronomy and geology does not even tend to qualify men to speak as experts on questions of evidence and historical criticism, which alone can determine whether the Bible is a revelation of the Infinite.

Few fields of research have been so fruitful in recent times as archeology. It has awakened dead civilizations and brought them into court with an impressive wealth of corroborative evidence from a source independent and hitherto unknown and so contributed more than physical science has to the greatest of all questions.

In his article on Science and the Supernatural, Dr. Anton J. Carlson seems to follow David Hume and others in saying a miracle is impossible and therefore not susceptible of proof by any testimony. But a physiologist is no better authority on that question than a mechanic. We all know that a miracle does not occur in the usual course of nature. If it did, it would not be a miracle and would be without significance.

But historians in general accept the Biblical narrative as true. The resurrection of Jesus is better authenticated than Caesar's invasion of Gaul. Its truth is a question of fact to be proved by evidence as we prove all questions of fact. Scientists will render a better service by keeping in fields of scientific research in which they have achieved so much.—GILBERT O. NATIONS.

The cry of the human for a life beyond the grave comes from that which is noblest in the soul of man.—HENRY VAN DYKE.

Dr. A. J. Carlson's superb article on "Science and the Supernatural" in the August issue is the best on the subject since Tyndall's famous Belfast address before the British Association.

The article to me, as a member of the Association, is worth many times the annual dues. It may give courage to others to smack supernaturalism and smack it hard, without offering any apologies.—WOOLSEY TELLER.

The article "Science and the Supernatural" in the August number of THE SCIENTIFIC MONTHLY lacks not only the necessary knowledge but also tact and reverence. It is insulting to realities which are sacred to me and to millions of other people. I have done scientific research in the field of biology, but I have never met a colleague who has lowered himself so far as to write the sort of incredible nonsense contained in the aforesaid article, which is an insult not only to religion but to science as well. I have learned to respect the opinions of others and I am able to tolerate ignorance so long as it is not associated with presumption, but I am completely unable and unwilling to respect the dogmas of a prophet of atheism.—P. B.

And will there, sometime, be another world? We have our dream. The idea of immortality, that like a sea has ebbed and flowed in the human heart, beating with its countless waves against the sands and rocks of time and fate, was not born of any creed, nor of any book, nor of any religion. It was born of human affection, and it will continue to ebb and flow beneath the mists and clouds of doubt and darkness, as long as love kisses the lips of death.—ROBERT G. INGERSOLL.

Just a word of congratulation for the brilliant article by Dr. A. J. Carlson on "Science and the Supernatural," appearing in the most recent issue of THE SCIENTIFIC MONTHLY.

We need a great deal more of such rational thinking.—AARON ADDELSTON.

I am frankly surprised that material of this sort should be accepted for publication in such a reputable scientific journal. I happen to be not only director of research but also a member of the Board of Trustees of a theological seminary, and I have a wide acquaintance among religious leaders of all sorts. I do not know of any reputable scholar, whether Protestant, Catholic, or Jew, who "believes in the supernatural." It seems to me that Dr. Carlson's thesis has about the same value as an attempt by a preacher to disprove certain scientific theories that

have not been held by scientific scholars for fifty years.

I do not agree with Dr. Carlson's definition of the scientific method which he says is "the rejection *in toto* of all non-observational and non-experimental authority in the field of experience." I would say that it is just as credulous to disbelieve in a thing without proof of its incorrectness as to believe in a thing that has not been proven. The scientific approach should imply an entirely open mind and should not reject anything "in toto" unless the rejection can be justified by observation or experiment.

Dr. Carlson confuses belief in the supernatural with religion. The two things are unrelated. It could probably be shown statistically that superstition is more prevalent among those who are not religious than among those who are. Dr. Carlson appears to know as little about religion as some theological scholars of my acquaintance know about science. These theological scholars will read the article with considerable amusement.—EUGENE AYERS.

So live, that when the summons comes to join
The innumerable caravan which moves
To that mysterious realm, where each shall take
His chamber in the silent halls of death,
Thou go not, like the quarry-slave at night,
Scourged to his dungeon, but, sustained and soothed
By an unfaltering trust, approach thy grave,
Like one that wraps the drapery of his couch
About him, and lies down to pleasant dreams.
—WM. CULLEN BRYANT

Would it be possible to secure additional copies of the paper in the August issue of THE SCIENTIFIC MONTHLY by Dr. Carlson? It states the situation so clearly and so forthrightly that I should like to be able to circulate it widely among my sociology students.—FRANK H. HANKINS.

It was pleasant to see Professor Carlson's "Science and the Supernatural" in your August issue and still more pleasant to find out that a man of his type can be elected president of the Association.—B. F. JAKOBSEN.

Dr. Carlson triumphantly proves in his article in the August number that the supernatural is not the natural and therefore not amenable to the scientific method. When he goes further and suggests that therefore it does not exist, he departs from the scientific method and uses supernatural methods just as much as if he killed a goat.—J. EDGAR PARK.

O may I join the choir invisible
Of those immortal dead who live again
In minds made better by their presence.
—GEORGE ELIOT

I think the title Science and the Supernatural is a misnomer as applied to Dr. Carlson's article. It could better have been called Science and Religion.

Now let's have an article by him: Science and the Extra-Religious Supernatural as an answer to Reading Your Mind in the August *Atlantic* and to that very interesting article in the July *Readers' Digest* about a Spiritualist of the early 19th century.—RUTHERFORD FULLERTON.

The article by A. J. Carlson in THE SCIENTIFIC MONTHLY was very decidedly offensive to me because of its gross materialism. I cannot believe it represents science.—S. G. B.

And now abideth faith, hope, charity, these three; but the greatest of these is charity.—I Corinthians, XIII, 13.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1944

CRYSTAL QUARTZ: MECHANICAL ALLY OF ELECTRICITY

By J. O. PERRINE

ELECTRICITY in its own right is not a useful commodity in everyday life. Charges of electricity, be they positive or negative, be they at rest or in motion, be they associated with matter or in their stark selves as electrons, are after all not much good per se in the welter of life. Rather it is the amazing capacity of electricity to enter into entangling alliances with various forms of power that makes it the greatest servant of mankind. On the other hand, air and water as such are vital necessities in the sheer fact of human existence. They, being more versatile than electricity, also play an important role in their embodiment and transmission of mechanical power for the world's work. Electricity has but a single task in life's affairs— to act as the number one intermediary and top ranking entrepreneur in the universal relations of heat, light, sound, mechanics, and chemistry.

Electricity is present at all times and in all things. It is here, there, and everywhere. Every substance and every object in the universe consists of an incomprehensibly vast and turbulent array of electrical charges—now called "electrons." Like the planets rotating about the sun, these tiny, invisible, and imponderable particles of pure electricity whirl without and within atomic nuclei. Electrical charges, negative and positive—electrons and protons—are the stuff out of which matter is made: a daffodil, a steel rod, a copper wire, a grain of wheat.

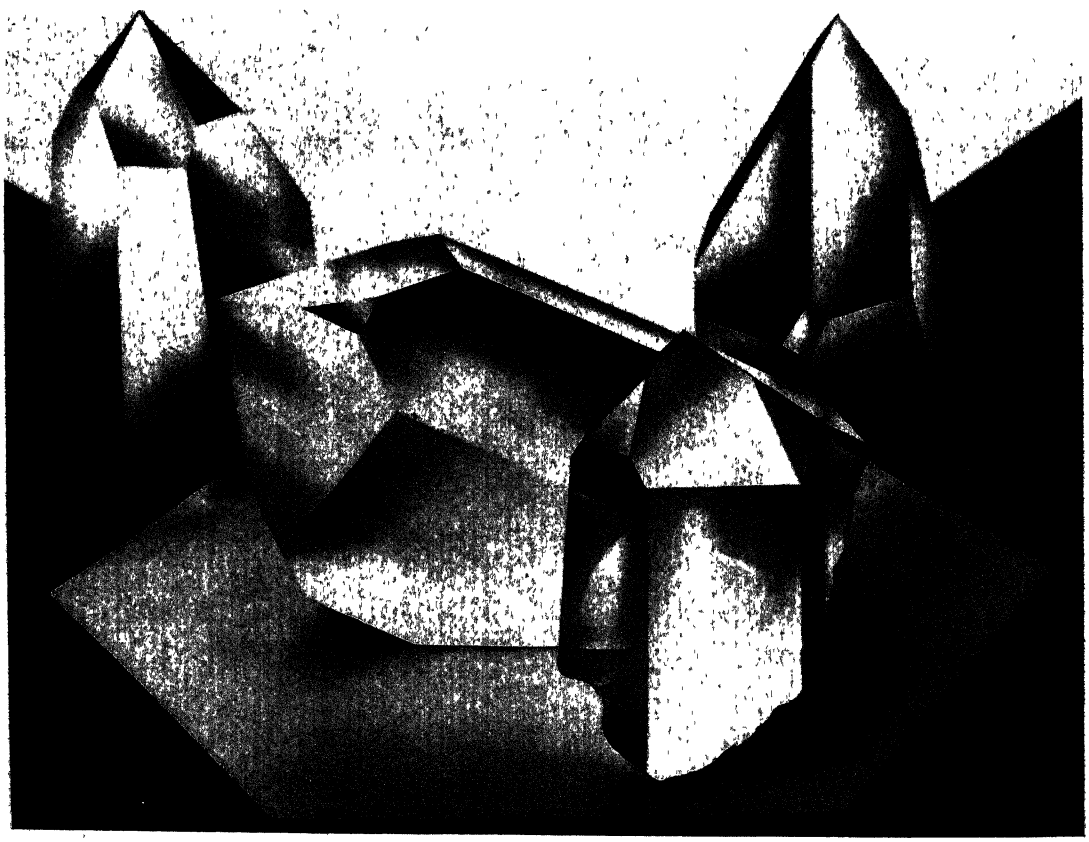
The problem of the scientist and the engineer has ever been to find out how to enlist the co-operation of electricity to do the job at hand. During the seventeenth century charges of high intensity which severely shocked animals and humans seemed to indicate that the only possible use of electricity was in the field of medicine. On one occasion in those olden times, 2,500 persons in a hand-to-hand line one mile long were shocked by a so-called static electricity machine. About 1776 an electric charge from such a machine was sent thirty miles across the Lombardian Plains of Italy to give a spark by which inflammable gases in Milan were exploded. In these manifestations of electricity, the charges were produced by friction; at least, that was the contemporaneous explanation of why things happened as they did. Sulphur, glass, and amber were vigorously rubbed by silk, furs, and woolen cloths in hand or by crude mechanisms to produce electrical charges of great severity. Today brisk scuffing of shoes on carpeted floors develops startling shocks when a metal doorknob is grasped. As it appears now, the sheer fact of friction has nothing to do with the basic phenomenon; the pressure involved in the tight rubbing is a means of making intimate contact between the two different substances. The electrical charges that exist in all substances, or it might better be said, the electrical charges out of which the atoms and molecules of all substances are made, are a restless and unhappy lot. Like the animal which thinks the grass over the fence is a bit greener than that of his own pasture, so the charges of electricity, the electrons in one substance, seem to have a disposition to go across boundaries and mix into another kind of stuff with which they are in contact. Electrons in one substance are in a terrific state of random unrest within that substance and are not at all in serene equilibrium with

electrons in other substances. There is a state of unbalance something like the unbalance of the atoms of salt and sugar in water. These substances dissolve of their own accord in water. They do so because of a solution tension, a driving force something like osmotic pressure. We do not know just why, except to say that a state of nonequilibrium seems to be quite the vogue in such matters.

Electric Alliances

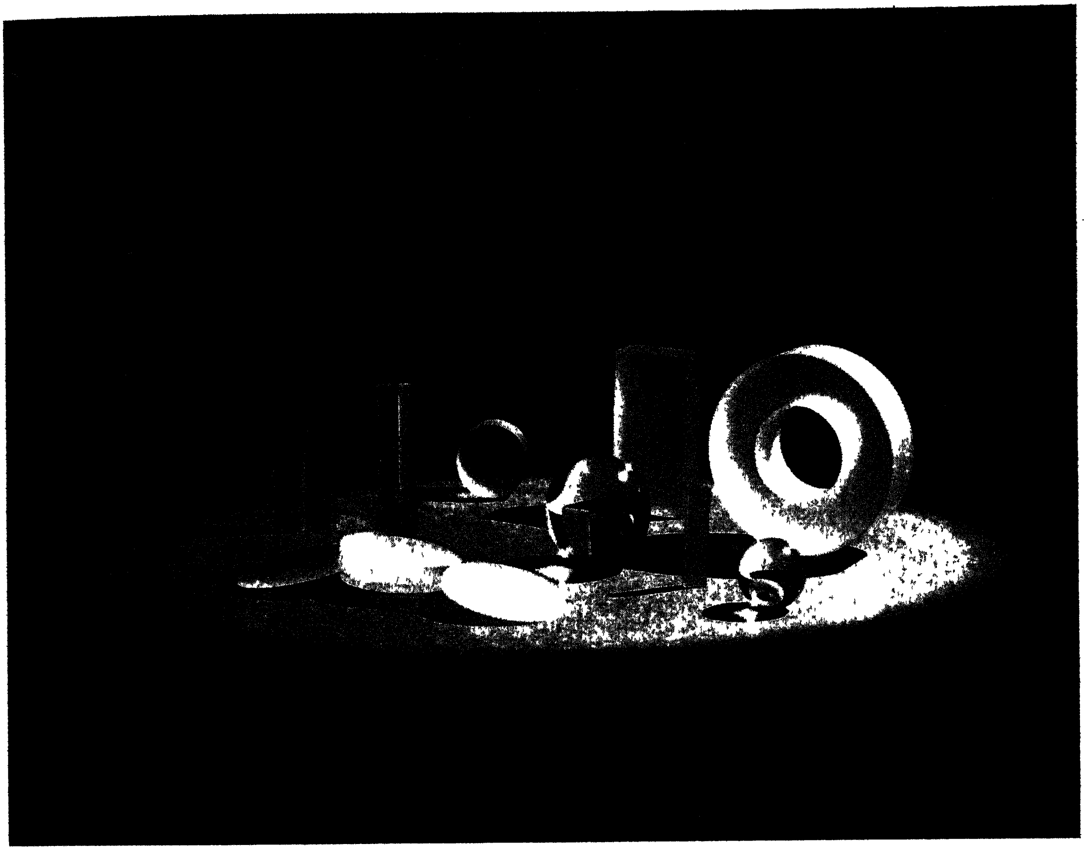
Electricity and Chemistry. Up to about the year 1800, therefore, electricity was not a very proficient agency in life's affairs, nor did it give much promise of becoming a useful tool of industry. One day, observations of the twitchings of a frog's leg by an Italian physiologist, Galvani, while working with scalpel and salt solution, suggested to his mind that the cause of the twitchings was electrical. There were no great blocks of sulphur and plates of glass and frictional machines to produce highly intense electrical charges in this case. The physiology laboratory became an electrical laboratory. The twitching of the frog's leg, which could be readily repeated without danger to the experimenter, indicated electrical phenomena of an entirely new variety.

So the first entangling alliance of electricity which gave promise of utility was an alliance between the electrons in metals and the electrons in a salt solution. As before in the contact of silk and glass, so the electrons in a metal in contact with a salt solution are not in balance, are not in equilibrium. There is an inherent electronic tension which drives electrons out of one into the other. Galvani's experiments were soon followed by those of Alessandro Volta who made the first electric battery, a series of copper and zinc plates interwoven by sheets of paper moistened with salt solution. Electricity was no longer a violent, intense, cruel,



About one-half natural size

QUARTZ CRYSTALS: MASTERPIECES OF NATURE'S LABORATORY



QUARTZ CUT INTO VARIOUS SHAPES

whimsical, useless agency. In the voltaic battery, electricity was tamed, serene, controlled, and amenable to do work, to do something useful.

Electricity Goes to Work. Perhaps the first task for an electric battery was the operation of the telegraph in 1844. The one-hundredth anniversary of that event was celebrated a few months ago. The electrical power embodied in the battery could be released by closing a key in a circuit. The electrical power sped with incredible swiftness along a wire and gave up its strength to operate a telegraph receiver. A click or a mark on a piece of paper served as a code for the transmission of information. The great epochal fact was that electricity had become a useful tool, a doer in the world's work. Many batteries with various chemical make-ups for all sorts of uses translate chemical energy to electrical energy and finally to light, heat, or motion in some desired endeavor. Storage batteries, which do not store electricity but which by chemical means store power in electrochemical form, serve today in automobiles, telegraph and telephone systems and give up their power to the assigned task.

It is important at this stage of the discussion to point out that in the alliance of electricity and chemical solution no motion is involved. A battery has no moving parts; no mechanics is involved in a voltaic cell in so far as it is a source of electrical power.

Several important and relevant ideas remain to be considered before the mechanical alliance of crystal quartz and electricity is presented.

Electromagnetic Induction. Electricity became an agent to translate power in enormous amounts by the discovery of the principle of electromagnetic induction. Here chemistry and electron solution tensions play no role whatever, but mechanical power

becomes the source of electrical power. In small and giant electric generators, the electrons inherently present and readily movable in copper wires are displaced in those wires by the sheer fact that the wires move with respect to a magnet. Why magnetic fields, those invisible and intangible auras about a magnet, impel the electrons in nearby wires to bestir themselves is not easy to understand. The basic facts of electromagnetic induction discovered over a hundred years ago by Oersted, Ampère, Faraday, and others are just as difficult to rationalize as is the voltaic battery. Suffice it to say that millions and millions of kilowatt-hours of work are done each day throughout the world by the transformation of the power in coal, in oil, and falling water to electrical power and back again to heat, light, and mechanical jobs of wide variety.

It is significant to observe that in electrical generators and motors motion is involved, and the principal item at issue is work, sheer work, hard work of some kind or other.

Dynamic Microphones and Loudspeakers. In translating the mechanical power of the vibratory motion in the sound waves of speech and music, it is important to note that the electromagnetic inductive technique is also extensively used in communication systems. In microphones, such as shown in Figure 1, the eighty or so turns of fine wire comprising the moving coil, or armature, weigh a tiny fraction of an ounce. The very thin dome-shaped diaphragm upon which sound waves pound with Lilliputian blows makes the coil move in a tiny crevice across which is a strong magnetic field. Electric currents are thus developed in the coil which are facsimiles of the sound waves. To be sure, if electric currents from another microphone and amplifier embodying speech and music are sent into the coil, this same structure becomes an electric motor; more specifically, a loud-speaker. In these cases, millivolts and milliwatts are needed to engineer the job instead of kilovolts and kilowatts. It is interesting that the principle of electromagnetic induction is a two-edged sword and is used for two such widely different objectives in power engineering and communication engineering. In the former, great amounts of power are reciprocally translated by the same philosophy as are the tiny amounts of power of the latter.

Thermoelectric Power. The heat energy

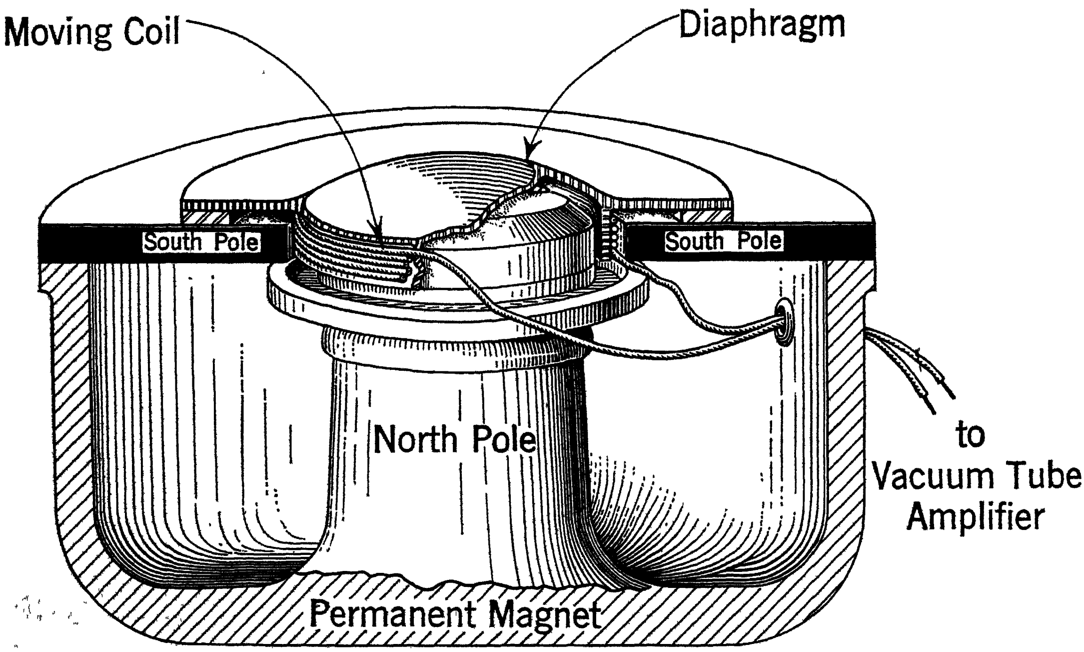


FIG. 1. MOVING COIL MICROPHONE.

of coal eventually becomes electrical energy through the medium of steam and electromagnetism. Chemical energy is changed to electrical energy in the many types of batteries. In the voltaic battery the mere contact of two substances gives rise to migration of electrons from one substance to another. Still another interesting and basic alliance of electricity is the direct and primary interchange of heat and electric energy. If a piece of copper and a piece of iron are twisted together, this same sort of migration takes place, but not very intensively. However, if heat is applied to that juncture, the turbulence is increased, and the migration is aided and abetted. In other words, the energy of heat is directly translated to electric energy. If the other ends of the wires are connected to a system capable of using electric power, then one has a different, an entirely different, kind of electric generator —not an electromagnetic, but a pyroelectric, generator. As long as a flame or heat in any form gives its energy to the junction of two metals, heat energy is directly changed to electric energy, and that electrical energy can be changed back to some other form of power.

The amounts of energy involved in this system, basically different from the two previously presented, are always very small The thermoelectric effect, or pyroelectric effect, would provide a very weak and also inefficient power translation system. Even if the sheer amount of power is not sizable, the phenomenon itself is very valuable in industry. A juncture of dissimilar metals becomes an électric thermometer. If the relation between temperature and intensity of charge, or voltage, is known, then temperatures in remote and generally inaccessible places can be readily determined. In great and intensely hot furnaces, the electric pyrometer is a valuable tool, not to provide power but to reveal temperature. As a matter of fact, the pyroelectric phenomenon is present in a single metal or crystal. If there is temperature difference between different sections of the same object, then an electrical tension, or voltage, exists between those different sections. As in the first alliance, no physical motion is involved in pyroelectricity.

Photoelectricity. Nature always seems to do things reciprocally. Chemical systems provide electrical systems, and electrical systems supply beautiful layers of silver from silver solutions on cutlery and silverware of various kinds. Tons and tons of aluminum are nowadays obtained from solution by electric deposition. In electrodynamic systems, motion drives electricity through wires, and electricity in wires produces motion. Sound power can be changed with great fidelity to electric power in sensitive microphones on the one hand, and, conversely, electric power supplied to receivers and loudspeakers produces clear speech and beautiful music. Electric power in wires is changed to' heat for ironing the frock, and heat per se can furnish a thermoelectric generator to reveal temperature. Electrons coursing through wires produce light But again in converse fashion the light itself can serve as the releasing agent for electrons which "pop" out of the surface of metals. In photoelectric cells the radiant light provides the means whereby the metallic surface on which the light falls becomes a source of electrons. Such photoelectric cells make it possible, therefore, not to measure temperature, to produce physical motion, to obtain transfer of light to electrical power in large measure, but to measure intensity of light. Again there is no mechanical motion and the sheer power is small, but the phenomenon is used as a technique in measurement for various purposes. Of particular value these days, the photoelectric cell is the key translating device in sound motion pictures, in telephotography, and in television. Rapid light variations are deftly changed to electrical variations, which are enlarged by vacuum tube amplifiers.

Crystal, or Pressure, Electricity. In the establishment of an electrical potential, or voltage, by the method of electromagnetism first discovered by Faraday in 1831, it was pointed out that the power of mechanical motion is translated to electrical power. The motion involved is the relative motion of a wire and a magnetic field which are not in physical contact. The physical structure of the coil of wire and the magnet suffers practically no change. There may be a small

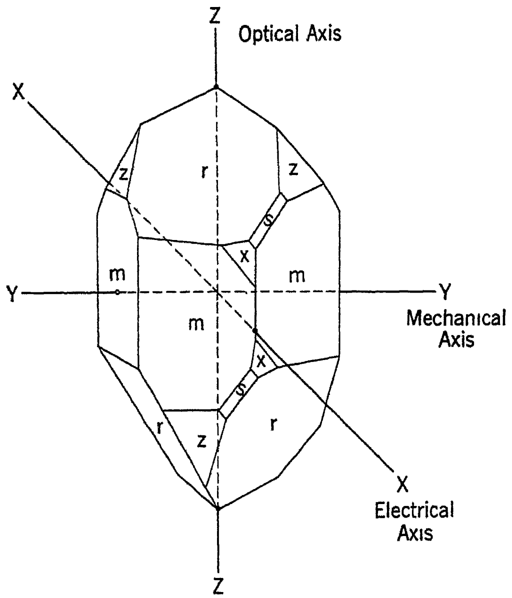


FIG. 2. IDEALIZED QUARTZ CRYSTAL

structural change, but that change plays no part in the mechanism of the energy translation. The mechanical power of motion has really played an indirect role. However, in certain forms of crystalline substances, mechanical power is directly changed to electric power. For example, if a crystal of quartz is mechanically twisted, compressed, or stretched, certain faces of the crystal acquire an electrical charge. This is indeed an entirely different kind of alliance between electrical power and other forms of power as presented in those alliances previously mentioned. It was pointed out that motions of the plates of a chemical battery do not enter into the matter at all; the wires of a thermocouple do not involve motion; the motion of the photosensitive surface of sodium, of potassium, of caesium, does not have a thing to do with the problem. In electromagnetic induction, distortion of the coils and magnets per se makes no contribution to the end result. However, in this last scheme of electric charge production, called "piezoelectric" or "pressure-electric," motion within the electrified object itself is a basically essential aspect of the phenomenon.

PIEZOELECTRICITY

Pyroelectric Crystals. Even though the quartz crystal is oftentimes regarded as a rather recent ally of electricity, it has been known for centuries to have electrical properties. Many years ago when the Dutch settled in Ceylon, they observed the natives playing with crystal tourmaline that had been thrown into a fire. Ashes clung to the heated crystal, and the name given to the crystal meant "ash attractor" in the Ceylonese language.

Magnetic attraction was a common phenomenon, and it is likely that the tourmaline was thought to acquire attractive properties in the fire. It is now believed that the phenomenon was pyroelectric. The first scientific paper regarding this subject was read before The French Academy. An English translation, 1742, was entitled "Of a Magnetical Stone Brought from the Island of Ceylon." In 1756, a German, writing under the Latinized name of Aepinus, presented the first rather comprehensive treatment of the subject and identified the phenomenon as specifically electrical.

Surprising as it may seem, a "History of Electricity" was written in 1767 by Joseph Priestley, discoverer of oxygen. In that history, the "ash attractor" phenomenon is listed as "electricity of the tourmaline."

Further investigation in this field was reported in a paper by A. C. Becquerel in 1828. He described experiments in which mechanical stress was applied to quartz and other crystals to produce a charge. Since it is now definitely known that some of those crystals are not piezoelectric, it is likely that the charges produced were not the result of mechanical strain but of the sheer contact incident to friction.

Pierre and Jacques Curie. Before Pierre Curie was stirred in 1896 by a later Becquerel (Henri) to study radioactivity, he and his brother, Jacques, knowing of the work of A. C. Becquerel, carried on researches on crystal electricity and published their results in 1880. It was they who first discovered the real pressure-electric effect and thereby introduced an entirely new concept of the interrelations of mechanical energy and electrical energy. In nature's treasure chest another jewel had been found. Truth is like a precious gem—it has many

facets. The Curies not only discovered the qualitative nature of piezoelectricity but also studied the phenomenon quantitatively. They made measurements of the voltages produced by unit pressures parallel to the principal axes of the crystals. One year later Lippman suggested that the crystal would be mechanically deformed if subjected to an electrical field, that is, connected to a source of voltage such as a chemical battery. The Curies promptly verified this prediction, and so the piezoelectric effect became recognized not only as an electromechanical but also a mechanicoelectrical phenomenon.

The piezoelectric effect, an intrinsically different alliance among the many entangling alliances in which electricity enters, took its place as a new actor playing an absolutely different role in the many relationships and interchanges of energy. It is not an uncommon phenomenon Many crystals can be given an electric charge on their faces by applying to them a direct mechanical twist or squeeze or tension. Particularly significant is the reciprocal aspect of electrical charge production by distortion of the crystal itself. If an electric charge from a voltaic battery or other source is applied to the faces of the crystal, a mechanical contraction or expansion or twist of the crystal results. Since crystals are usually definitely elastic, they may be set in mechanical vibration along some dimension by the application of an electrical charge. In this direct association of electrical charge and mechanical motion, there comes into the realm of electrical science an entirely different philosophy and possibility of application than those that apply to other fundamentally basic electrical phenomena.

Modus Operandi of Piezoelectricity As has been stated, electrons and protons are the building stones of the atoms of all substances. In many, perhaps in most substances, and particularly in the noncrystalline form, the atoms are in great confusion; they are in great disarrangement and move about in chaotic, random, and restless fashion.

However, the outward appearance of crystals (Fig. 2), irregular in shape to be sure but very symmetrical and systematic in that irregularity, presents evidence of great regularity of atomic and molecular arrangement. Many crystals assume very precise and beautifully regular angles, shapes, and facets. Furthermore, the inner architecture of the atoms and molecules is the result of definite and orderly patterns of grouping and alignment. By X-ray studies of crystals the orderly groupings of their atoms are recognized and the distances between the atoms of many molecules in crystals are quite well established in their precise alignments. Furthermore, the electrons within the atoms

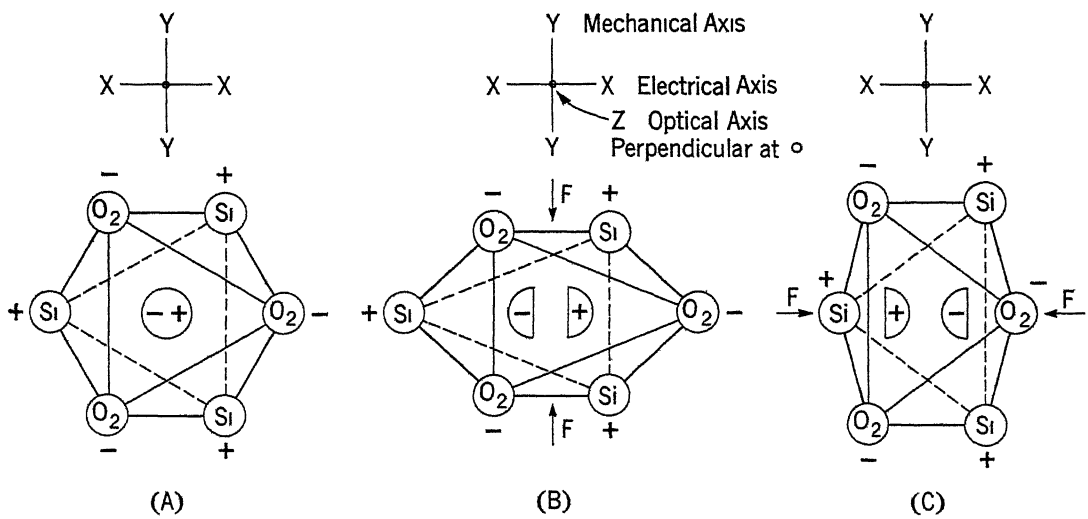


FIG. 3. DIAGRAM OF A QUARTZ CRYSTAL, SILICON DIOXIDE

A, NORMAL; IN B AND C FORCE F DISTORTS MOLECULE AND CAUSES IT TO BECOME ELECTRICALLY CHARGED.

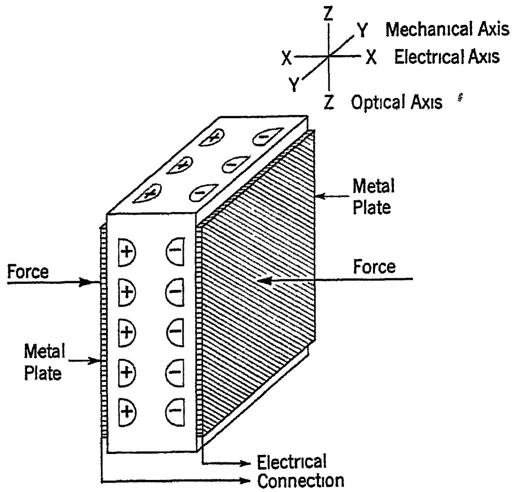


FIG. 4. TRANSFORMING ENERGY
MECHANICAL ENERGY BECOMES ELECTRICAL ENERGY AS FORCE IS APPLIED TO PLATES HOLDING CRYSTAL

and molecules of crystals are arranged in regular fashion, which presents the possibility that a change in shape of the crystal would produce such a rearrangement of electrons that one portion of the crystal would have a seeming excess of electrons and another portion a scarcity of electrons. Thus would be brought into being an electrically charged crystal, as this excess and dearth would happen simultaneously to millions and millions of molecules.

In Figure 3A is depicted the approximate arrangements of positive and negative charges in a molecule of quartz. Looking down along the optical axis of a quartz crystal, one would see an equally angled hexagon. Quartz is an oxide of silicon, SiO_2. The silicon atoms have positive charges and the O_2 have negative charges. The combined effect of the three positive charges is the same as though all three were at the center of the equilateral triangle of which they form the corners. The same is true of the three negative charges. At the center of the hexagon the two opposite charge effects are equal, and the crystal is neutral electrically. Mechanical energy is necessary to disarrange the electrical neutrality and separate the positive and negative charges at the center. When the crystal is squeezed from top and bottom, the center of "positiveness" is no longer at the original central point but has moved to the right (Fig. 3B). Likewise, the center of negativeness has moved to the left. It took work to bring about this separation, and there is electrical evidence of that work because the right portion of the molecule is positively charged and the left portion is negatively charged.

When the squeeze is applied horizontally rather than vertically (Fig. 3C), the left-hand portion of the crystal molecule gets a positive charge and the right-hand portion a negative charge.

The arrangement of atoms and their accompanying charges in quartz happens to be such that mechanical force and motion change the positions of the centers of "positiveness" and "negativeness," and the crystal acquires an electrified condition, evidence that energy has been transformed. In other words, the crystal is pressure-electric, piezoelectric. This phenomenon does not occur in all crystals. Based on the symmetrical arrangements of their molecules, crystals may be grouped under thirty-two classifications of which twenty are piezoelectric and twelve are not.

The piezoelectric effect, like so many basic phenomena, has a long and laboriously earned heritage. As has been said, the brothers Curie first quantitatively studied a quartz crystal by putting a weight on the surface and measuring the charge, the magnitude of which was proportional to the applied weight. In Rochelle salt crystals the electrical voltages arising are greater under the same distortion than for quartz. With a sharp, heavy blow as much as 2,000 volts can be produced on the faces of a Rochelle salt crystal. A small neon lamp may be made to flash by the direct transformation of mechanical power to electrical power and finally to light. When such a crystal is connected to amplifier and loud-speaker, very slight taps on the crystal become loud crashes of sound. The tiny jarrings of the balance wheel of a watch placed on the crystal produce enough distortion of the crystal and consequent voltage to make the ticking of the watch blast out of a loud-speaker.

A narrow and thin plate of Rochelle salt crystal about the size of an army lieutenant's bar serves very well as a microphone. The Lilliputian impact of the sound waves of speech and music of the order of one micro-

pound distorts the crystal sufficiently to give rise to electrical charges which can be amplified. The variable resistance microphone, such as the carbon transmitter, and the electrodynamic and condenser microphones are now joined by the crystal microphone to translate the mechanical variations of sound waves to electrical variations.

In Figure 4 the central block is a piezoelectric crystal. Metal electrodes are attached to the side faces of the crystal. If forces are applied as indicated by the arrows to squeeze the crystal horizontally, the right surface of the crystal will acquire a negative charge and the left surface a positive charge. If the faces of the crystal were pulled, they would be charged oppositely. The actual "thinning" of the crystal by the squeezing forces would be very small, particularly in the case of quartz, since it is a hard substance. If a negative electric charge were applied to the right face and a positive charge to the left face, then the crystal slab would be squeezed. If two slabs of Rochelle salt 10 millimeters thick and 4 inches long are held together and poled in opposite directions so that one slab expands when voltage is applied and the other contracts, the direct change of electrical energy to mechanical energy is nicely visible. The arrangement above-described reminds one of a bimetallic thermostat. With only 90 volts applied, a direct motion of a quarter of an inch of the end of the dual crystal is produced.

Applications

Piezoelectricity Grows Up. In general the piezoelectric effect remained a scientific curiosity until the war of 1914–1918. During its youth, it had been the subject of considerable scientific investigation. Lord Kelvin, the eminent and famous electrical engineer and physicist, proposed in 1893 a mechanical model to explain the cause of piezoelectricity and was able to calculate the numerical relations involved. In 1910 in the *Lehrbuch der Kristall Physik* Voigt gave the mathematical expressions relating stresses, strains, fields, and polarizations of crystals.

During World War I Professor Langevin in Paris devised a quartz plate receiving device for the purpose of detecting the underwater sound waves of submarines. Conversely, if electrical charges were applied to the quartz plate of his device, the crystal would expand and contract and send out a sound wave. As he did not perfect his detector till after that war, it was not used at that time actually to detect submarines. His apparatus was, and is, extensively used to determine rapidly the depth of the ocean by timing the sound echo from the bottom.

During the years in which Langevin was working in the field of piezoelectricity, A. M. Nicolson of the Western Electric Company was experimenting in the same field. Using Rochelle salt crystals, which give much larger piezoelectric charges and displacements than quartz, he constructed and demonstrated microphones, loudspeakers, and electric phonograph "pickups." However, these uses of the crystal had no particular advantages over other previously well-known techniques. The direct alliance between motion and charge was still in the category of a curiosity and was not yet a particularly and especially talented phenomenon to achieve a practical purpose not otherwise possible.

Crystal Vibrations. Crystals are elastic and therefore, like a coiled spring, vibrate within themselves. A plucked string and a rigid rod vibrate visibly. A solid block of material like quartz can vibrate in various fashions. A cube of jelly will shiver and swing and sway and totter forward and back. This "tottering" of an elastic mass is called a shearing vibration. If a slab of quartz is squeezed, it will start to vibrate along its length when the force is suddenly released.

A crystal plate is an extremely complex vibratory system with a large number of degrees of freedom, that is, possibilities of motion. These various possibilities are, for the most part, combinations of certain fundamental types of vibration. The general relation between stress and strain, which in an ordinary isotropic medium involves only two constants, requires six constants in crystal quartz The choice of a particular constant, or constants, that enters into a given mode of vibration depends upon the orientation of the plate with respect to origi-

FIG. 5. FREQUENCY CONTROL CRYSTAL
EACH FREQUENCY MODULATION (FM) SET REQUIRES 10 CRYSTALS LIKE THE ABOVE. EACH TANK RADIO SET USES 70 AND ARTILLERY SETS CONTAIN 110.

nal crystal axes and the particular type of vibration; whether longitudinal, transverse, shear, etc.

A crystal or any elastic object has a number of frequencies at which its vibration may be maintained with small impulses from the outside. These are its natural frequencies. It can be forced to vibrate at any frequency by the application of sufficiently great outside forces, but at certain particular frequencies its vibration will continue for a considerable time when once started and this vibration can be maintained with very little energy if the force is applied in step, in tune or in synchronism. The block of crystal acts like a pendulum. The frequency of a mechanical pendulum depends on its length. The frequency of a particular quartz plate depends on its dimensions and its elastic constants. The elastic constants of quartz are high, as evidenced by the fact that sound, which is a mechanical vibration, travels along a particular path through quartz at the rate of about 14,000 feet per second; a velocity comparable to that in steel and nickel. Since quartz plates can be made small and thin and since quartz is highly elastic, very high frequency of vibration can be achieved by this technique. Thousands of vibrations per second and even millions of cycles per second enter the picture. The significantly important idea about a quartz "pendulum" is that its mechanical vibration is directly linked to electrical changes or vibrations. Since a particular quartz plate has a particular natural frequency mechanically, it will be directly allied with that same frequency of electrical vibration. In all sorts of vacuum tube oscillators and generators which provide alternating electric currents of high frequency and in all sorts of communication circuits, it has always been significant that there were no moving mechanical parts. The electric currents were oscillating, and the electrons were scampering, but the coils, condensers, wire, and vacuum tube parts did not mechanically move, and mechanical vibrations had nothing to do with the matter. But the mechanical vibrations and the natural frequencies of quartz plates have now entered the realm of, and play a part in, electrical vibratory systems. The mechanical vibrations per se are the crux of the matter, and it is striking to realize that mechanical vibrations are present and directly play a role in electrical systems. Nicholson used a Rochelle salt crystal with its association of mechanical vibrations and electrical vibrations to serve as a generator of electrical vibrations. The vibration was started when the circuit was closed. With a vacuum tube amplifier in the system, it fed back a bit of electric power to keep the crystal mechanically vibrating by the converse piezoelectric effect. The device thus served as a primary source, a crystal oscillating source of alternating current. This was indeed a new concept, a new technique.

Professor G. W. Pierce of Harvard University made important contributions to this new technique. Professor W. G. Cady of Wesleyan University first showed that quartz could be used not only to produce but also to control nicely and precisely the generating of electric currents by vacuum tube oscillators of the previously known type. These crystal-controlled oscillators were later applied to govern the frequency of broadcasting stations and mobile radio transmitters and receivers in war equipment (Figs. 5 and 6). The crystal plate is a sort of electrical vibration "governor."

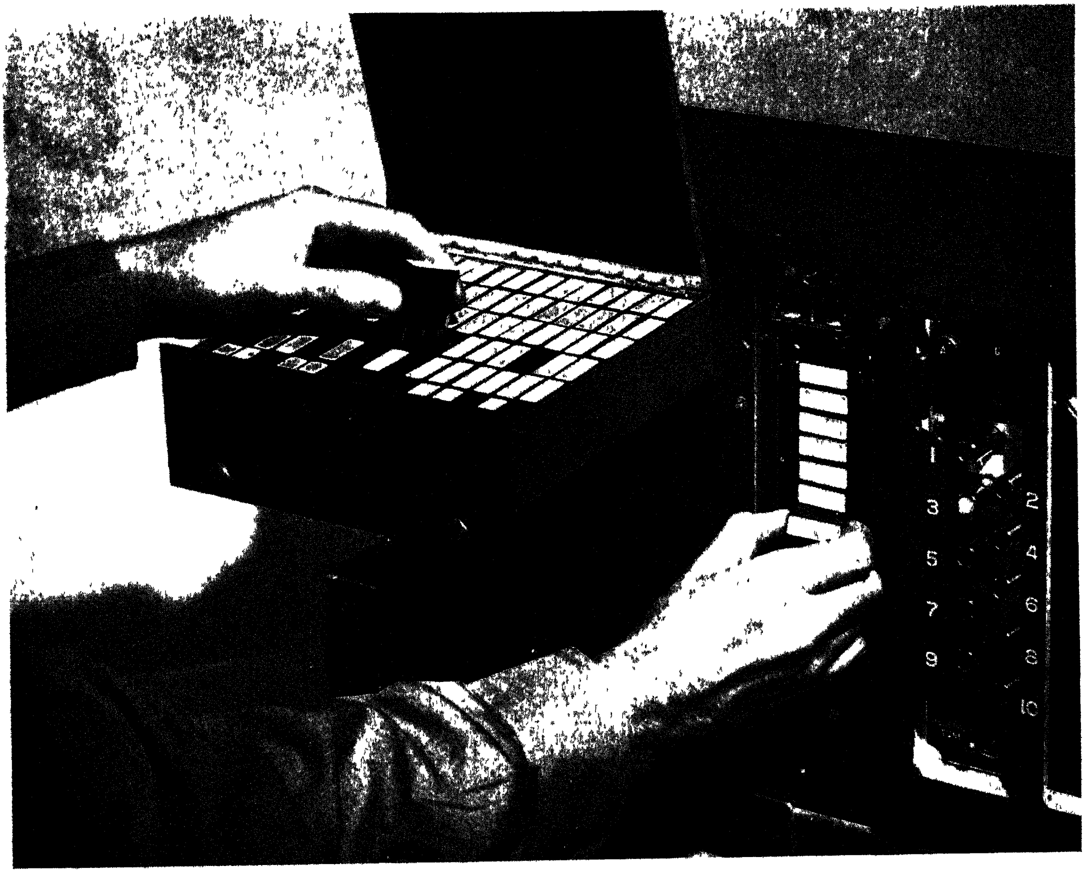


FIG. 6. SET OF CRYSTAL PLATES IN A TANK FOR ITS RADIO TRANSMITTER
THE OPERATOR PLUGS IN THE PROPER PLATES FOR THE DESIRED FREQUENCIES TO BE USED ON A PARTICULAR MISSION. THE PUSH-BUTTON CONTROL ON THE EXTREME RIGHT PERMITS QUICK CHANGES OF OUTGOING WAVE.

Measurement of Seconds and Minutes. The swinging of the chandelier in the cathedral at Pisa suggested to Galileo that it might be used to measure time. Checking the time of the back and forth motions with his heart beat, he can be said to have invented the pendulum clock. Before and since Galileo's observation, the measurement of time has ever intrigued man's imagination and engaged his ingenious talents. The hour glass, the balance wheel of the watch, and many other schemes have been used as well as the ticktock of the stately clock. W. A. Marrison of the Bell Laboratories used the highly accurate alternating electric impulses of quartz crystals to measure time. This was a new and unique technique applied to a very old profession. The piezoelectric crystal did not have a pendulum but it did have a mechanical vibration due to its elastic properties and therefore was a sort of clock, a real electric clock of usually fine precision.

Of particular interest and significance is a recent announcement from Greenwich, England. For decades the word Greenwich has been synonymous with time, accurate time, world time, latitude and longitude. Purely mechanical devices—extra special chronometers and clocks, checked by the stars in the sky—have been used to measure time and tell time with great accuracy to just folks and to engineers and scientists wherever they may be on land or sea. Now it has been disclosed that the piezoelectric quartz crystal oscillator, a real electric clock, is to be put in service at Greenwich. For astronomical use, crystal clocks not only have great stability but also are completely free from the effect of the earth's force of gravity. At the earth's poles pendulum clocks swing faster

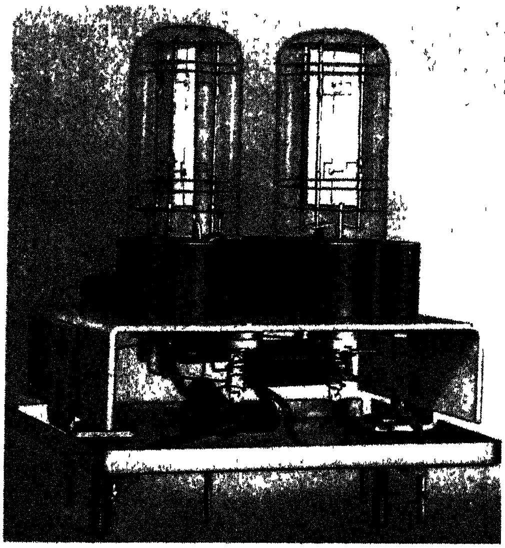


FIG. 7. CRYSTAL WAVE FILTER
THE QUARTZ PLATE IS PLACED IN A VACUUM BULB.

than at the equator, but crystal oscillators retain their precision of vibration wherever they may be taken on the earth's surface, deep in the ocean, or high up in the sky. Early in the development of crystal clocks, an accuracy of one part in a million was achieved. Now crystal clocks are available with a daily deviation of well under one part in a hundred million. To put it another way, these newest quartz crystal chronometers beautifully measure time to an accuracy of one one-thousandth of a second per day. The old faithful mechanical clocks at Greenwich which have served so well for many years are due for quite a shock, an electric shock, when they are put on the shelf by a shivering wafer of rock.

Electric Current Filters. A crystal plate has a particular and a sharply defined mechanical frequency of vibration. At this frequency it will keep vibrating with very little applied power. If it is placed in an electric circuit along which many alternating currents are traveling, the crystal acts as a "door" or "gate" to that electrical frequency which corresponds very precisely to its own electromechanical frequency. It tends to stifle the other frequencies but gives the "green light" to its own. Hence a quartz crystal plate would be a fine electric filter of electrical currents. It would provide a sharply resonant circuit. Professor Cady was the first to make this application of the electromechanical vibrating crystal. W. A. Marrison of the Bell Telephone Laboratories made further developments along this line and designed a filter for a narrow group or band of frequencies.

To the rapid developments in electrical vibrations with a direct mechanical accompaniment, L. Espenschied of the Bell Telephone Laboratories made a further significant contribution. Taking advantage of the knowledge of the so-called "equivalent electrical circuit" concept applied to a crystal, given by K. S. Van Dyke of Wesleyan University, Espenschied showed how to combine electromechanically vibrating crystals with other electrical elements in ladder type electrical networks to provide wider pass-bands than are available with crystals only. For such filters the detrimental effects of electrical resistance in the coils and condensers contribute to rounding off the attentuation-frequency relations and prevent the obtaining of as sharp a cutoff as can be obtained by crystals alone. The final step in utilizing crystals in wide-band crystal filters was made by W. P. Mason when he devised the "resistance compensated" lattice type of crystal electric wave filter. With this type of filter the electrical resistance in the concomitant coils and condensers produces only an additive loss independent of frequency and results in a filter with as sharp a cutoff as can be realized with crystals alone. This type of filter is used in the high-frequency carrier current telephone systems and in the coaxial system which simultaneously transmits 480 messages over one pair of wires. Following this development have come the significant and important researches of R. A. Heising, W. P. Mason and their associates—Lack, Bond, Willard, Sykes, McSkimin, Greenidge, D'heedene, Thurston, and Fair—of the Bell Telephone Laboratories. Now crystals with their electromechanical vibrations play an accompanying role with electrical vibrations per se to auxiliary coils and condensers in electrical arrays or networks of a wide variety and of wide capabilities and talents. These networks or filters have been directly responsible for the progress achieved in the wide

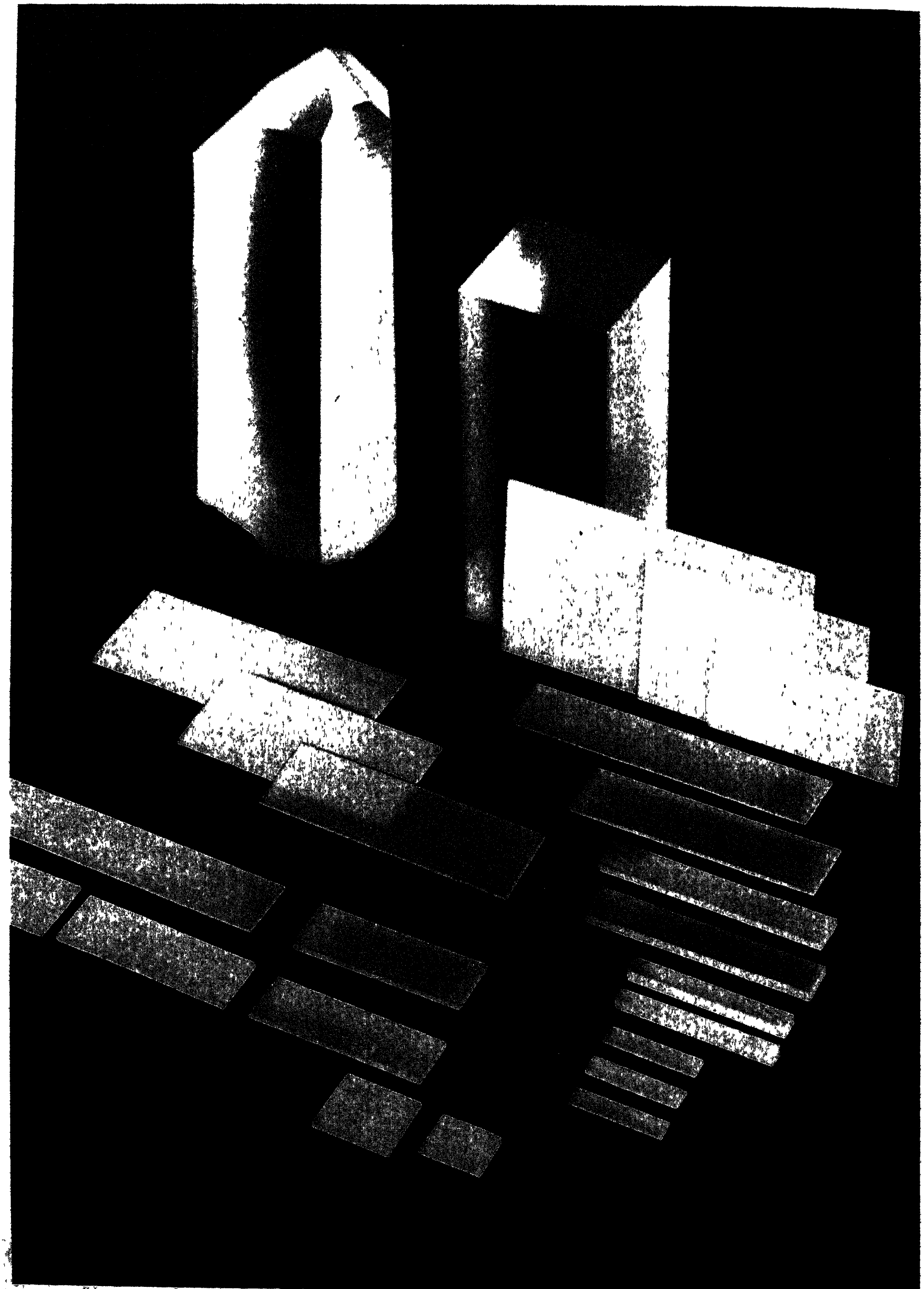
wave-band characteristics necessary when a number of telephone messages are sent simultaneously over the same pair of wires. Such electric wave filters (Fig. 7) provide very selective and sharply defined devices which with great nicety separate the array of currents carrying different telephone conversations over the same wires. The characteristic of the mechanical quartz plate with a particular natural frequency of vibration corresponding to that frequency of electric currents specifically aids in sharpening the edges of the electrical "door." An electric wave filter is a kind of electrical "door" which passes electric waves of wide array in frequency. But the "door" may have "rubber" edges like subway doors which provide a little leeway to passengers squeezing in. Good electrical filters or "doors" ought not to have "rubber" edges. Electrical vibrations either too few or too many in a particular case must not be allowed to "squeeze" through. Quartz crystals help make the wave limits of filters sharply defined and sharply different from other wave filters. Thus it is possible to bring wave channels closer together than by previous techniques. Through the discriminating talent of the sharply edged crystal electric wave filter, frequencies from 60,000 cycles to 2,060,000 cycles are nicely divided in 480 separate bands of frequencies, each about 4,000 cycles wide.

Quartz Crystals

Crystal Cuts. In this essay the basic phenomenon of piezoelectricity and its unique contribution in electrical vibrating systems have been presented in a general way. The details of theory and practice and design, all so necessary for the accomplishment of a practical operating system, are the combined contributions of many men and would fill many volumes. Quartz crystals are contributing in large measure to the war effort. Thousands and thousands of items of communication equipment on the home front and on the war front rely on detailed piezoelectric crystal engineering for their outstandingly successful operation. In 1943 one manufacturer alone provided 8,000,000 quartz crystals for special war communication equipment. In 1939 about 20,000 were cut. The concluding part of this exposition will deal briefly and generally with some points about the various "cuts" of quartz plates (Fig. 8).

The native quartz crystal is really a thing of beauty. Its irregular regularity and multiple facets make an intriguing object. Many crystals are strikingly clear, and their surfaces are smooth as satin. Since the days of the Old Testament writers, quartz crystals have been a symbol of clarity and beauty. It is a common crystal and is found in many places throughout the world. Nature's laboratory with its gigantic test tubes seems to have done a particularly good job in Brazil. There in the river bottoms and in the rocky hills, quartz of high quality is found in great plentitude. Some crystals weigh ounces and fractions thereof; others weigh hundreds of pounds. One highly perfect individual crystal weighing about half a ton arrived in New York a year or so ago. Its 6 cubic feet of volume would make it the "Cullinan" of quartz crystals. All quartz is not of the same crystallographic shape. Figure 9 shows a particular side view of a particular crystal and the bird's-eye view of that crystal. About the only general statement that can be made about quartz crystals is that a bird's-eye view of all crystals always reveals an equal-angled hexagon and sometimes an equal-sided hexagon. A quartz crystal is a complicated structure. Its physical properties vary in different directions. Along different paths the coefficients of elasticity, the coefficients of thermal conduction, the coefficients of thermal expansion, the velocities of sound, the velocities of light, and the piezoelectric relations are different.

The natural frequencies of a particular plate wafer, block, or ring of quartz depend largely on its dimensions and how that plate is cut with respect to the different faces and axes of the original crystal. A particular plate may vibrate in various ways. It may simply expand and contract along one or more axes or may undergo a complicated motion of bending and shear. One is reminded of the motion of the accordion with its combination of squeeze, twist, and bending. Obviously if the temperature changes, the density changes, the coefficient of elasticity changes, the velocity of mechanical motion (sound) through it changes, and



About seven-eighths actual size

FIG. 8. BLOCK AND PLATES ARE SAWED OUT OF NATURAL CRYSTAL

finally, as the end result, the natural frequency of a particular "cut" changes.

In developing crystals for oscillators and communication circuits, extensive studies were undertaken in the Bell Telephone Laboratories to determine how "cuts" of different sorts were affected by the variable physical factors of quartz. Perhaps the particular physical property of a certain magnitude along one axis could be neutralized by slanting the cut to that axis so that the different magnitudes of that property would produce a null result. In other words, an attempt was made to find the "cut" best suited to a particular purpose.

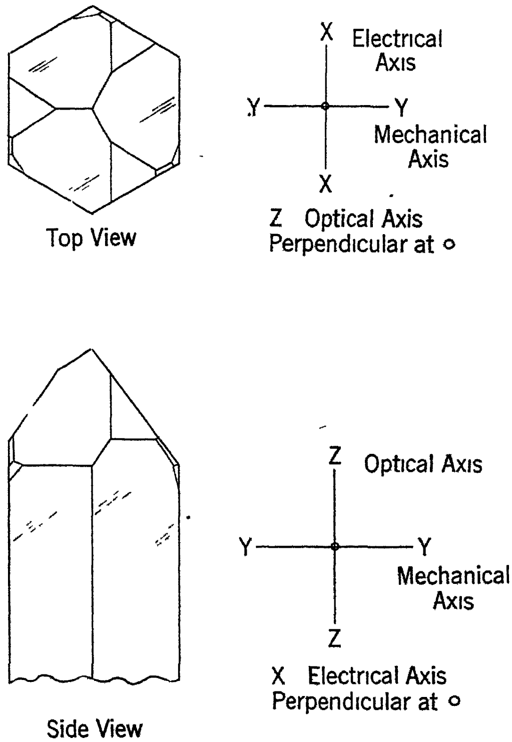


FIG. 9. QUARTZ CRYSTAL

X, Y, Z Axes. The vertical line perpendicular to the hexagonal cross section and passing through the center thereof is given the designation "Z-axis." It is also called the "optical axis." Light passing along that axis travels with uniform velocity. Light passing at some angle to the optical axis is doubly refracted, resulting in two different velocities.

The Y, or mechanical, axis is taken perpendicular to any pair of the three opposite faces. This axis is of course horizontal, assuming the Z-axis as the vertical axis, and intersects the Z-axis. The X, or electrical, axis also is horizontal and passes parallel to two opposite faces of the crystal. The X and Y axes are in the equatorial plane. The three axes are mutually perpendicular and intersect at the center of the hexagonal cross section (Fig. 9). One is reminded of the three co-ordinate axes of solid analytical geometry.

The first "cuts" used were X-cut and Y-cut. Both of these cuts have their width parallel to the Z-axis. The X-cut has its face perpendicular to the X-axis and its length parallel to the Y-axis. The Y-cut has its face perpendicular to the Y-axis and its length parallel to the X-axis. These three cuts and their orientation are shown in perspective in Figure 10.

If an alternating voltage, i.e., an alternating electrical charge, is applied to an X-cut plate along the electrical axis, X, the plate expands and contracts lengthwise along the mechanical axis, Y; namely, at right angles to the charge displacement. The frequency in this case depends largely on the length of the crystal, that is, its length along the Y-axis.

If an alternating voltage is applied to a Y-cut plate along the mechanical axis, Y, then the resultant motion is a shear. The two faces of the Y-cut crystal move back and forth along the X-axis in their own plane. Again one is reminded of a cube of jelly which totters. The top horizontal plane of the jelly cube moves back and forth in its own horizontal plane parallel to the fixed lower plane resting on the dinner plate.

As indicated in Figure 3, a motion along the electrical axis, X, will give rise to charges displaced along this same axis. Conversely, if an electric charge is applied along the X-axis, one gets a mechanical displacement along that X-axis. In other words, the mechanical and electrical displacements are not at right angles but in the same direction. Vibrations may be longitudinal or transversé with respect to the electric field. Thus the X-cut crystal can be made to vibrate along its length parallel to the mechanical axis Y, or it can be made to vibrate along its thick-

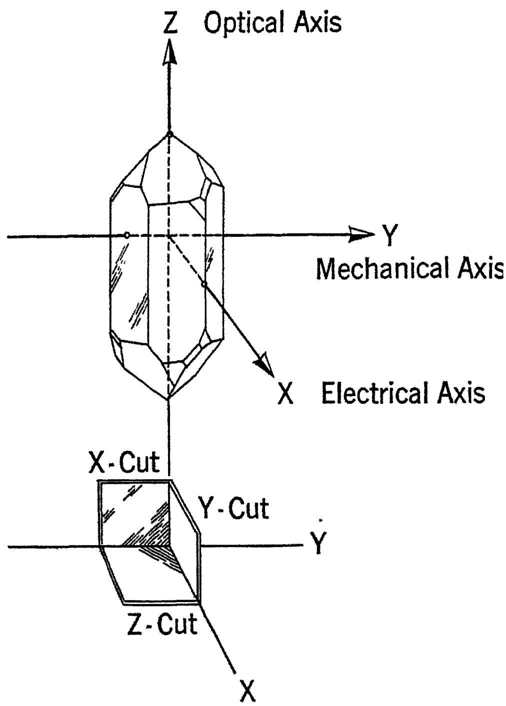


FIG. 10. ORIENTED QUARTZ CRYSTAL SHOWING CUTS IN RELATION TO NATURAL CRYSTAL.

ness parallel to the electrical axis, X. The two surfaces would move at right angles to their own planes, and the plate would alternately get thinner and thicker. One is again reminded of the motion of the accordion. Obviously the frequency involved when the plate is caused to vibrate lengthwise along the Y-axis would be slower than when it vibrated along its thickness, or perhaps one ought to say its thinness.

If an effort were made to get a high frequency by utilizing the vibrations along its thinness, slight changes in various conditions might cause the controlling vibrations to shift from its frequency to an upper harmonic of its Y-frequency. The most common cause for this undesirable condition would be a temperature change. In other words, X-cuts and Y-cuts are very vulnerable to temperature changes.

Crystal Frequency. When an X-cut crystal is executing X-axis vibrations, its thinness largely determines the frequency of its natural mechanical vibration and of course its accompanying alternations of electric current. As in all vibrating systems, frequency and wave-length are related by the simple equation:

$$\text{Frequency} \times \text{Wave-length} = \text{Velocity}$$

In this case, the "thinness" of the X-cut plate is one-half of a wave-length for the mechanical vibration in the quartz. The two surfaces of the plate are loops or antinodes of motion in the longitudinal vibration. If the plate is vibrating in its fundamental, then its thickness is the distance between two adjacent loops of motion and is a half wave-length. However, the actual situation is not as simple as above suggested. The vibration is not strictly longitudinal but has a shear component.

However, if one knows the velocity of mechanical waves, that is, of sound, in quartz along the particular path concerned, then a good idea of the numerical value of the mechanical frequency and electrical frequency of a particular plate of X-cut crystal for X vibrations can be found by doubling the thickness of the plate and dividing the 2t into the velocity.

For example, a .1 inch plate gives a wave-length of .2 inch. Since $F = V \div L$, the resulting frequency is 843,400 cycles or 843.4 kilocycles per second. This calculation gives a fair approximation as to the order of magnitude of F, since V is not accurately known. It does give a good notion of the fundamental mechanical wave phenomenon involved.

Velocity of waves in an elastic medium is a function of the square root of the coefficient of elasticity and the square root of the density.

$$V = \sqrt{\frac{E}{D}}$$

The equation for vibration of quartz crystal plates in such cases as above can be written

$$F = \frac{1}{2t}\sqrt{\frac{E}{D}}$$

with proper attention to units.

These equations are difficult to use exactly as such since the value of E which controls the velocity along the different axes varies with the cut of the crystal. Furthermore, on account of the shear motions, the length and breadth dimensions also play a part in the frequency of the mechanical vibrations.

From the equation F = Velocity ÷ 2t, giving the mechanical frequency at which a crystal plate vibrates, it is readily seen that since the numerator is large, 14,000 feet per second, a small change in thickness of a thin plate produces a considerable change in that frequency. Since the electrical frequency accompanying the mechanical frequency must be highly accurate in communication equipment, the precision with which crystal plates are ground elicits great admiration of the skill of the artificer. Thousandths, ten-thousandths, and millionths of an inch are the terms necessary to describe the dimensions to which crystals are ground and polished.

Assume, as before, a crystal is .100000 inch thick, thereby supplying a frequency of about 843,400 cycles per second. A change in thickness of a thousandth of an inch to .101000 inch produces a reduction of 8,350 cycles. This change is a bit less than one per cent. An increase of a ten-thousandth and a hundred-thousandth to .100100 and .100010 reduces the frequency by 880 and 84 cycles respectively, a change of about .1 and .01 per cent. Finally, if the thickness of this assumed plate were increased by a millionth of an inch to .100001 inch, a change of 10 cycles would result. This is a change of about .001 per cent. The latter values of .01 and .001 per cent are very small and, as pointed out in the succeeding paragraph, frequencies can be achieved which vary by about .002 per cent. Hence it is seen that the thickness must be prescribed within very tiny tolerances. Likewise, the length and breadth must be controlled with extreme care.

The fine techniques and niceties of the jewel maker and the lapidarist are surpassed in this new task of cutting and grinding crystals for the manufacture of electrical communication apparatus.

Temperature Affects Frequency. To get quartz crystal electromechanical vibrators of more stable and reliable character independent of temperature changes, a very thorough and extensive investigation was embarked upon in the Bell Telephone Laboratories. The accompanying photograph (Fig. 11) shows an enlarged model of a quartz crystal and plates cut at various angles and

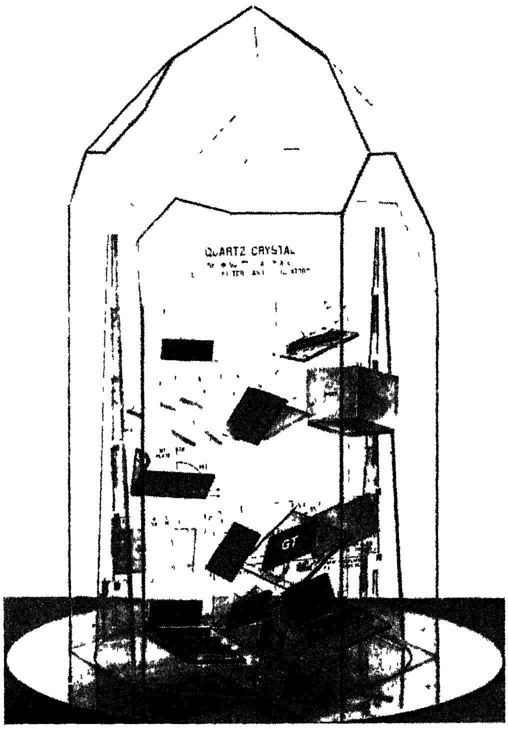


FIG. 11. MODEL OF QUARTZ CRYSTAL SHOWS ORIENTATION OF VARIOUS CUTS IN CRYSTAL.

rotations with respect to the X, Y, and Z axes. One cut tried early by W. A. Marrison was a doughnut-shaped piece of quartz. From Figure 12 it will be observed that the Y-axis runs through the center of the hole. By properly proportioning the dimensions, the change in frequency with temperature can be made essentially zero. Crystals of this type were used in early forms of crystal clocks for keeping time very accurately and for frequency standards in various fields of endeavor. They have now been replaced by GT-type crystals described below. The 60-cycle frequency of great power generators is controlled by some such crystal structure so that the electric motor clocks in the home and in the office may be nicely correct.

A piece of rock weighing about an ounce acts as a governor to control the speed of rotation of a giant structure weighing tons and converting thousands of mechanical horsepower to electrical power. One is reminded of David and Goliath.

The doughnut-shaped crystals did not lend themselves very well to electric wave filters in carrier telephone systems as typified by

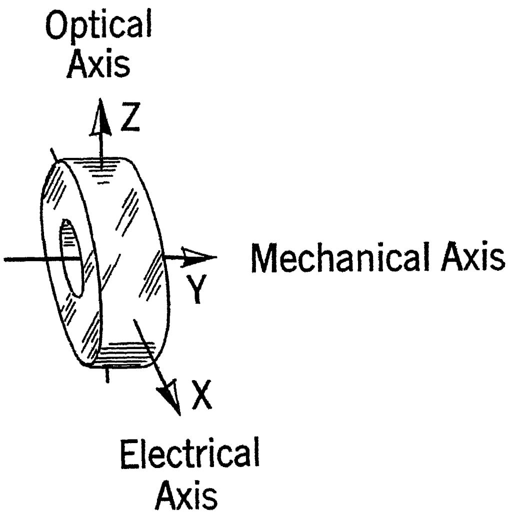


FIG. 12. DOUGHNUT CUT
THIS CUT HAS A ZERO TEMPERATURE COEFFICIENT.

the 480-channel coaxial cable system, in radio broadcasting transmitters, in radio transmitters and receivers for airplanes and tanks, and in various war devices. Therefore, crystal plates, or wafers, are used. These plates were formerly mounted in aluminum cans. Exactly cut and ground to the desired size and coated with very thin metallic electrodes, a recently developed technique puts the plates inside a vacuum bulb as shown in Figure 7. The absence of air around the plates increases the delicacy and sensitivity of operation.

One of the cuts worthy of particular mention is the so-called GT-cut devised by W. P. Mason. This cut resulted in especially fine and practical crystal plates which are practically insensitive to temperature changes. The manner of the GT-cut can be generally observed in Figure 11. Over a range of 100 degrees centigrade, i.e., from the freezing to the boiling point of water (180 degrees Fahrenheit), the GT-cut crystal is constant in frequency capability to about two parts per million of cycles per degree. Other well-known cuts are the AT, BT, and NT. The Radio Corporation of America developed an excellent cut, called the "V."

The fundamental studies of crystals and crystal cuts and crystal functioning in communication facilities have been accompanied by extensive research on methods of cutting and grinding quartz plates to the orientations and dimensions desired. The grinding tolerances are very small, and the success in producing high-precision crystals in large numbers for war purposes during the last few years has been possible primarily because of these studies.

Epilogue

The piezoelectric effect is a most fascinating phenomenon. Quartz crystals can be appropriately called the latest ally of electricity. This entire field of endeavor is unique in the saga of electrical engineering because in the application of quartz crystal plates to electrical communication a vibrating mechanical structure is an integral operating part of an electrical system. A mechanical device directly contributes electrically to the functioning of an electrical system.

The piezoelectric alliance is not a suitable or efficient method of translating mechanical power to electrical power. Like the thermoelectric and photoelectric alliances, its talent is not applicable where great amounts of power are needed for the world's tasks. To be sure, in piezoelectric generators for underwater signalling, sound waves embodying power in the order of a kilowatt are now used. The potent mechanical vibrations are imparted to the crystal by vacuum tube oscillators and amplifiers. However, one kilowatt is not gigantic so it may be correctly stated that the really big jobs are done through the chemical and electromagnetic alliances. However, in those branches of engineering where high-frequency vibrations and oscillations play a role, the direct electromechanical converse relations of the piezoelectric effect so nicely present in crystal quartz serve admirably.

As has been said very appropriately by W. P. Mason:

> The science of piezoelectricity was born about 64 years ago, lay dormant for about 40 years, but during the last 25 years has advanced at such a rate that it can be regarded as one of the foundation stones of the whole art and practice of electrical communication.

In Dr. Mason's significant statement, the word "stone" is for the first time used literally as well as figuratively in electrical engineering.

GOKKANOSHO: A REMOTE CORNER OF JAPAN

By JOHN F. EMBREE

EIGHT centuries ago Japan was torn with civil war, a war of two great clans, the Minamoto and the Taira. In 1185 there was a final disastrous sea battle between them at Shimonoseki during which a child emperor, held by the Taira, was drowned and the whole Taira clan wiped out. This, at any rate, is the orthodox historical account. Tradition, however, clings to the romantic belief that many of the defeated Taira warriors fled south into the wild mountain fastnesses of central Kyūshū, and the brothels of Shimonoseki were, for a brief spell, enriched with noble ladies. To this day, so it is said, descendants of the Taira are to be found in Gokkanosho (Fig. 1), a district far in the mountains of Kumamoto, approachable only by foot.

A more prosaic, if more scientific, interest centers on Gokkanosho as an example of Japanese mountaineer life. Gokkanosho means five settlements or families and originally consisted of five *mura*, or villages: Kureko, Momigi, Hagi, Nitao, and Shiibaru. For administrative purposes two other *mura* are now included (Kakisako and Kuriki), making a total of seven *mura* ranging in population from 150 to 2000 people, all governed by the same headman and council. The administrative office and headman are located in Kakisako, the largest one, but each *mura* has its own head, or *kuchō,* who takes care of local affairs.

In the summer of 1936, while making a field study of the social organization of Suye Mura, a Kumamoto rice farming village, I took a few days off for a pilgrimage to this interesting place which, while considered to be almost in another country by people of the village in which I was living, was actually less than twenty miles away.

To prepare for such an arduous journey by foot as that to the mountains of Gokkanosho, three things are regarded as essential by a Japanese: a small cotton towel, or *tenugui,* a hat, and tissue paper. The hat keeps off the sun and the rain, the *tenugui* serves to wipe the sweat from one's brow, and the tissue serves as handkerchief or toilet paper.

Three companions and myself were to leave the village at 6:30 in the morning, but, in good local style, we were not under way till after seven. Everyone wanted to know where we were off to at such an hour and all with knapsacks, and when they discovered that we were going to Gokkanosho they opened their eyes wide; no one in the village had ever been there. They wondered whether the people there were like other Japanese—since they did not eat rice they must be different from all right-thinking, rice-eating people!

From the neighboring village of Youra a bus took us well up into the mountains. In the valley where I had been living, the wide flood plain of the Kuma River is one vast irregular checkerboard of rice paddies. As one goes up toward the mountains, the rice fields gradually become scarcer and are replaced by forests, upland fields, and an occasional lumber mill.

After a couple of hours' ride, we came to Miyazono, a settlement of one house, located by a mountain stream. This house functioned as shop, hotel, and dwelling. The storekeeper informed us that the chief products of this region are charcoal and lumber and that the inhabitants eat wheat and millet. As rice is scarce, it is purchased only for special occasions.

Beyond Miyazono houses occur only at widely separated intervals and are bark or tin-roofed one-room shacks instead of the richly thatched cottages of the plains. Many people of the region make a living by carrying charcoal. We met three women carriers who said they make two trips of 20 *cho* (1½ miles) a day at 12 *sen* (4 cents) per sack, earning a total of 48 *sen* (16 cents). Stronger people, they said, can make three trips. Because their loads weigh up to 100 pounds (12 *kwan*), they must rest frequently, but they do not lack for beautiful scenery, nor do they

make machines of themselves. Frequent stops are made by some little stream to rest, chat, and munch a cucumber (Fig. 2).

We went along a narrow mountain trail where the mountains rose high all around leaving but little sky visible. The forests vibrated with the song of myriad insects. As we walked, the noise of a rushing mountain torrent sang constantly in our ears, and every now and then we caught a glimpse of the water tumbling from a rock and foaming into a bright green pool.

Some of this plentiful water power is harnessed for electricity, as evidenced by an imposing modern power house by the river. This plant supplies Kumamoto City with electric power, yet farm houses a few miles away are still using oil lamps (Fig. 3).

Finally, after several hours of tiring uphill walk, we reached the settlement of Kureko, one of the seven hamlets of Gokkanosho. The first regular farmhouse we came to was a tin-roofed hut near a bridge. Here some people directed us to the schoolhouse where we ex-

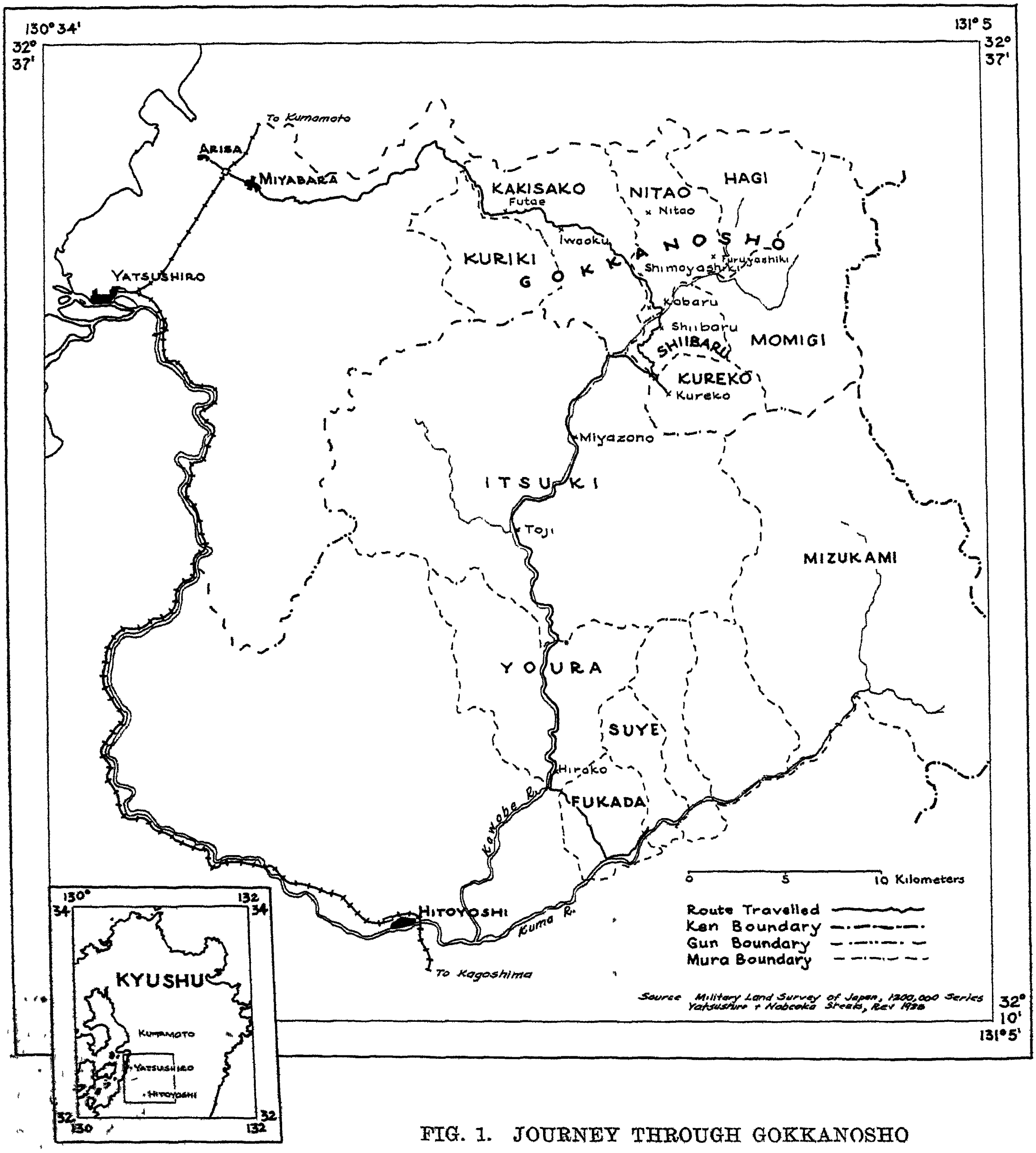


FIG. 1. JOURNEY THROUGH GOKKANOSHO

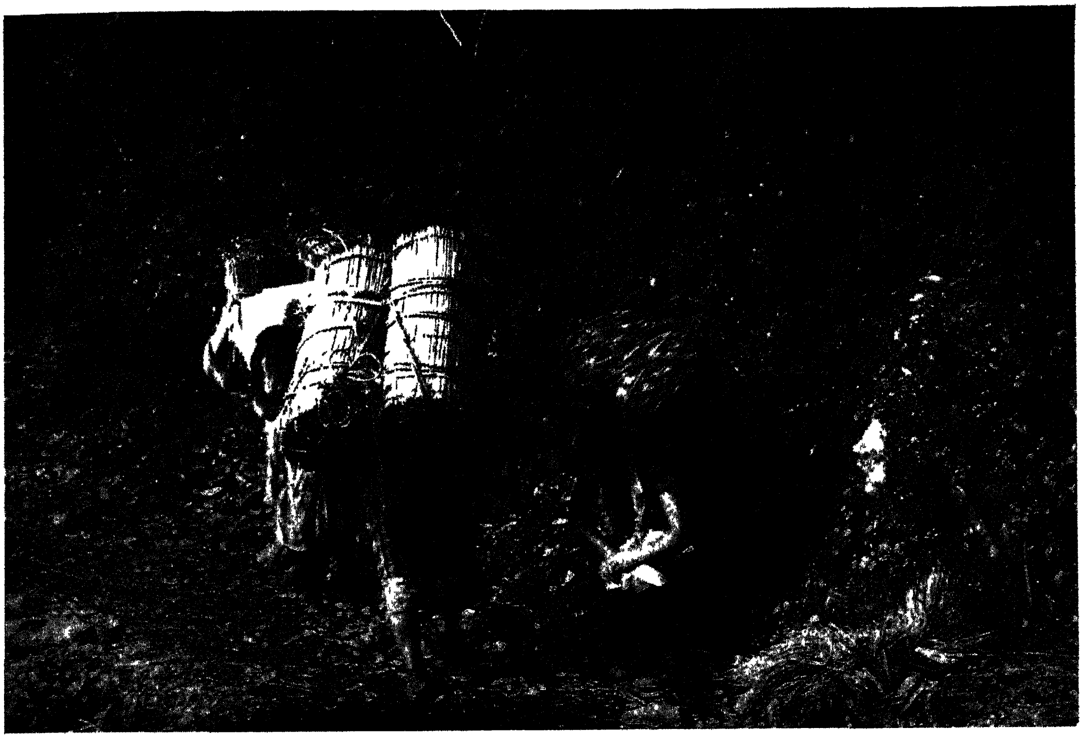


FIG. 2. CHARCOAL CARRIERS NEAR MIYAZONO
THESE WOMEN CARRY THEIR BURDENS ABOUT SIX MILES A DAY FOR THE EQUIVALENT OF SIXTEEN CENTS.

pected to spend the night. We walked on and up a steep path, feeling very tired, and finally came to a house. It was an old, dilapidated structure with a heavy thatched roof buried under a profusion of moss and bushy green plants—the kind of house a goblin might haunt, or a ghost of the Taira (Fig. 4).

A few steps farther on we came to the school, a small one-room wooden structure, but it was closed, the teacher being away on summer vacation. As we stood by the school gate wondering what to do for a night's lodging, a woman bent low under a load of faggots called a greeting to us. We told her our plight, and she invited us to follow her just as casually as if strangers were an everyday occurrence. So we walked along behind her by upland fields of maize and potatoes, millet and buckwheat. On the steep mountain sides across the valley we could see great squares of cleared land. These were the *koba,* or mountain fields, where *hie,* a poor sort of mountain grain, is grown. Every now and then we passed other dwellings, each more overgrown than the last, and finally came to the home of our guide, a house with a roof as fertile as any. One would never suspect it of being the local headman's house. But when we learned that one man has been headman for twenty years, we realized that time in Gokkonosho is not the same thing as time in Tokyo.

On arrival at the home of our volunteer hostess, we gave the headman's wife some of the rice which we had brought with us. She took it and left us. Shortly afterwards, having changed from working clothes to a full-length kimono and having combed her hair, she reappeared and served tea.

About dusk, after we had each had a bath in turn in a rude tub out in the back yard, the master of the house, his son, and the son's wife returned home from their day's work in the fields. After washing and changing, they came in and sat by the fire pit. Then supper was served to them—a potato broth helped out with pickles. We were served our rice in the guest room, but after finishing we joined the family around the fire pit, partly because the evening had become chilly, but more to become acquainted with our host, Mr. Kuramoto, and his family.

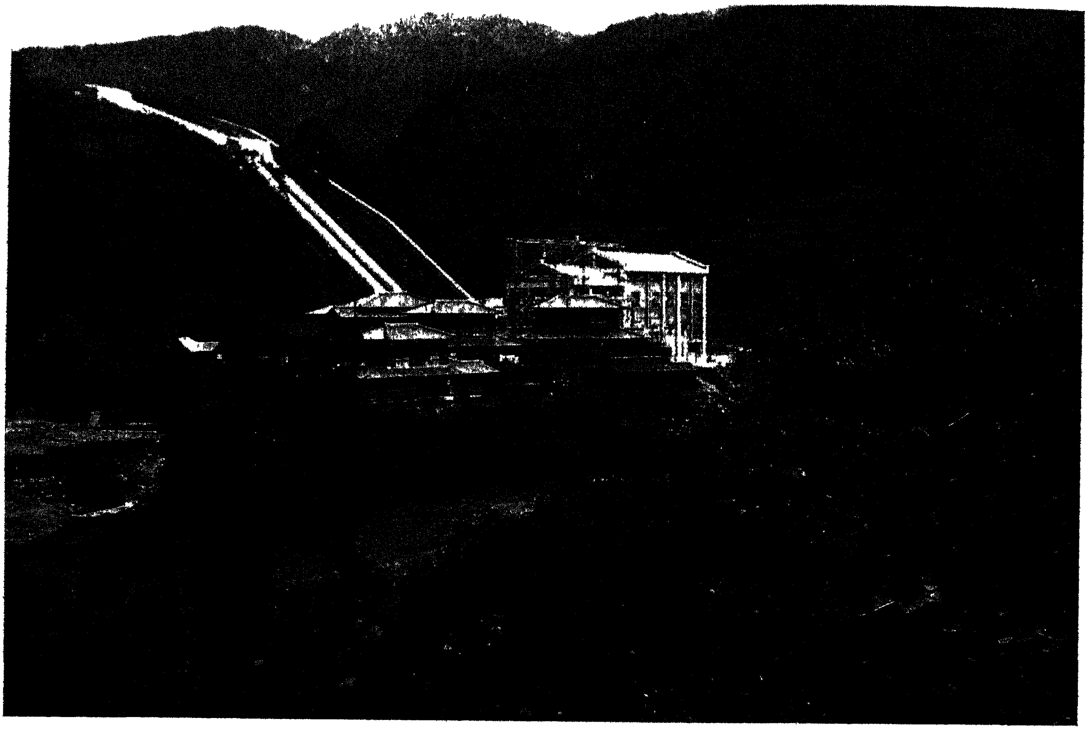


FIG. 3. HYDROELECTRIC POWER PLANT ON THE KAWABE RIVER
THE LOCAL FARMERS USE OIL LAMPS WHILE THEIR POWER PLANT ILLUMINATES A DISTANT CITY, KUMAMOTO.

As head of the hamlet of Kureko, Mr. Kuramoto says he receives 80 *sen* a year from each of about thirty families. Marriages and deaths may be recorded by him instead of at the central administrative office of Gokkanosho, which is many miles away by tortuous mountain trails.

After a little further conversation, I learned that the daughter-in-law was from the same community of Kureko. As women of other regions cannot do the hard work required of a Gokkanosho woman, the men marry women of the same region, often of the same settlement. As there are only thirty families in Kureko, everyone must be fairly closely related, though the inhabitants maintain the fiction that they do not marry relatives.

Seven people live in the Kuramoto house: Kuramoto and his wife, their first son and his wife, and three grandchildren. Three other grandchildren died young, the price of mountain life, where infants stand scarcely a fifty-fifty chance to live. A few years ago there was a midwife in Kureko, trained at Kumamoto City on the recommendation of the village headman, but she was not called in by very many mothers. A woman usually has her baby alone and washes it herself. Her mother or brother may give her a pail of water, but that is all. Mrs. Kuramoto remarked that if a woman cannot wash her own baby when it is born, she is a useless woman. A doctor is never called here unless a person is in a critical condition, and by the time the physician arrives from many miles away, the patient is usually dead.

There is a belief in other parts of Japan that several brothers and their families all live under one roof in Gokkanosho, but this is not true. In former times, however, they may have done so, Kuramoto conceded. Co-operation between households is characteristic of life in Kureko as in other parts of rural Japan. For instance, two or three households group together to clear one another's mountain fields (*koba*) or to collect firewood. If a new house is built, the whole hamlet assists in the work. By this co-operation the families get the work done more efficiently; the practice also makes for friendship among neighbors.

As in other parts of Japan, a go-between is used in marriage negotiations. This go-between is often the uncle or elder sister's husband. Unlike most places in Japan, there are no naming ceremony parties. At a funeral the entire hamlet helps, but, unlike other parts of Kumamoto, four young male relatives of the deceased, usually nephews, carry the coffin. Possibly because more relatives are on hand, functions which are relegated to nonrelatives in other places are performed by relatives in Gokkanosho.

As we talked of life in the mountains, the daughter-in-law made up our quilts for sleeping and washed the supper dishes. We soon retired, glad of the warmth of the thick quilts and of a good night's rest.

In the morning the family was up at five. After breakfast, the dishes were again washed—in cold water—the fingers making a characteristic rubbing sound against the glaze of the bowls. The daughter-in-law did all this, carrying the baby on her back as she worked.

A remarkable blessing of the region, which we discovered after spending the night, was a lack of mosquitoes. This is attributed to the cold. The cold is also given as a reason for not growing good rice, although the rough terrain is probably a more important one.

One does not punch a time clock in rural Japan, so after breakfast the men sat about a while for a smoke and chat, then the elder Kuramoto set off for the hillside five miles away, while his son sharpened a sickle on a grindstone (Figs. 5 and 6). This done, he too set off, and his wife followed soon after carrying a lunch box of wheat in a basketry bag on her back. Water is carried to work in bamboo containers. The small children all stayed home and spent the morning in play to the accompaniment of a pleasantly noisy mountain stream.

We spent the morning exploring the hamlet. From the children we learned about the local school. It has, they said, one teacher and forty-eight pupils; there is a six-year course; and also a "completing" course (Hoshugakkō) of one year, all taught by the one teacher. No children are sent away to

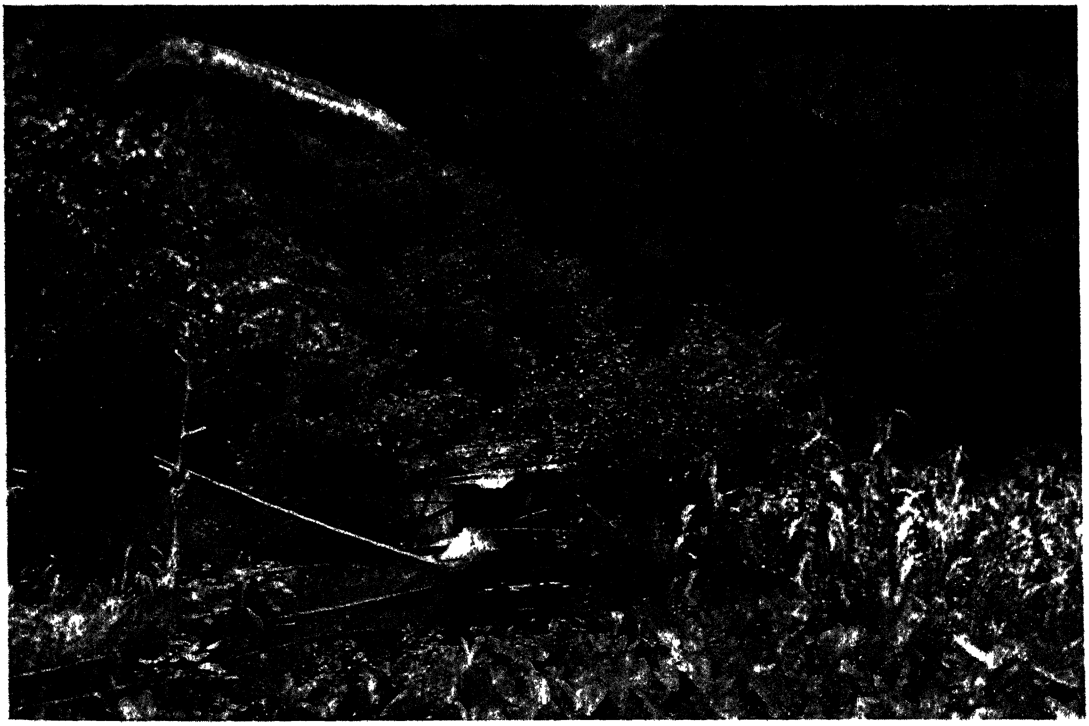


FIG. 4. A THATCHED ROOF, "BEARDED WITH MOSS AND IN GARMENTS GREEN"
IN THE FOREGROUND IS A VEGETABLE GARDEN OF CORN AND TARO. A MOUNTAINSIDE FORMS THE BACKGROUND.

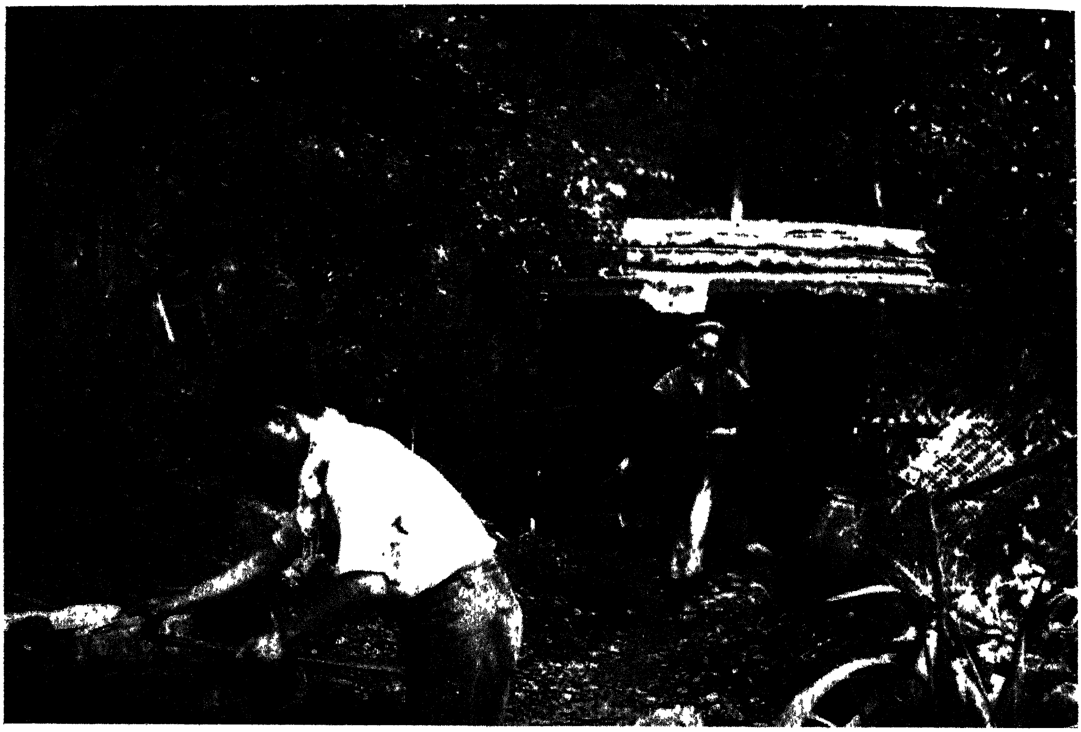


FIG. 5. PREPARING FOR THE DAY'S WORK IN THE FIELDS
THE BOY SHARPENS A SICKLE WHILE HIS MOTHER "DOES THE DISHES." BEHIND HER IS THE "BATHROOM."

school for there is no money in Kureko for such luxuries. By way of extracurricular reading I noticed two books in our host's house, one on the growing of secondary crops in mountain villages and one entitled *How to Marry*.

As the *koba*, or mountain fields, are two or three miles off and difficult of access, people do not come home for lunch. It takes much time to care for *koba*, so the people do not have the leisure seasons of the rice plains people. Whenever Mrs. Kuramoto goes to Fukada to visit a relative there, she envies the people sitting around.

One *koba* is productive for about four years, though a good one might last a couple of years longer. When the soil is depleted a new one must be prepared in a different place. Bushes are burnt as fertilizer, no other fertilizer being used. A new field made one year has its growth cut and burnt and is then left to lie fallow till the following spring when it is planted. The series of crops is usually buckwheat the first year, millet (*hie*) the second, red (*azuki*) bean the third, and finally Italian millet (*awa*) in the fourth year. Fields where corn is planted are always those where buckwheat, *azuki*, and millet have once been planted. The few little rice fields in Kureko average 4 *se* (0.1 acre) and total only 1 *cho* and a *tan* (2.7 acres) in the hamlet (in other parts of Kumamoto each landowner might have 1 or 2 *cho* of rice land). The average *koba* land and upland field area is over 1 *cho* (individual *koba* are 1 to 2 *tan*). Human fertilizer is used in the rice fields, an indication of their special value.

The chief export products of Kureko are mushrooms, bamboo shoots, and tea, also some red beans and *konyaku* tuber. Supplies come from a branch of the Miyazono store; goods are paid for in cash or in red beans (in the rice regions of the plains small purchases are paid for in rice).

A sign of change in life here is the plan to inaugurate a farmers' association, similar to farmers' associations in the rice-growing regions, for the marketing of mushrooms.

Telegrams reach remote Kureko by foot from Haramachi, another hamlet of Gokkanosho, and a postman comes from Kobaru.

Of over thirty families, three take a newspaper: the hamlet head, the schoolteacher, and the forestry office. Electricity is not available here; only oil lamps and the old-fashioned square lanterns called *andon* are used. Wood, not charcoal, is used in the fire pit There are three phonographs but no radio. A teacher tried a radio once, but found it difficult to run, since he depended on batteries. Other contact with the outside world comes through occasional trips to Fukada or other villages of the plains and through itinerant peddlers or merchants who come occasionally to sell something or to buy mushrooms. Most of Japan is overrun with bicycles, but there is not a single one in Kureko. The only practical way to travel the steep and narrow mountain paths is on two legs.

Work varies with the season. In winter, when the fields are covered with snow, people must sit at home. In summer, however, everyone rises at five, works till noon and, after a lunch in the fields, resumes work till five or six and retires at ten. Wheat or millet must be boiled for the next day's lunch box the night before.

There are plenty of vitamins in the food of these mountaineers. White potatoes and pickled radish and greens form the staples of diet. Rice is served only on special occasions. But there is a long list of other vegetable foods including various herbs and greens, sweet potato, cucumber, pumpkin, maize, millet (both *hie* and *awa*), wheat, buckwheat, and various beans. Eggs occasionally supplement this diet.

Every house has a small flower garden, and many have pet birds, kept in cages (Fig. 7). In the barn of the house we visited, there were curiously shaped offering vessels made of *satogara,* an edible plant, for the popular deity Jizō. *Shōchū,* a rice liquor, is put in them for the Jizō festival once a year.

The morning turned out to be a fine one after the mists rose. We visited a small grass-roofed wayside shrine, or *dō,* for Jizō, who is said to keep disease away from the hamlet. The *dō* also houses the images of three other deities: Kwannon, Shaka, and Daishi—all of them newly gilt. They are celebrated by three groups of eight or nine

FIG. 6. A JAPANESE MOUNTAINEER
LUNCHBOX IN HAND, HE IS ABOUT TO SET OFF FOR A DAY'S WORK ON HIS DISTANT MOUNTAINSIDE FARM.

families, each contributing buckwheat cakes on festival days. The festivals follow the lunar calendar: Jizō the 14th of the sixth month, Kwannon the 15th of the tenth month, and so on. The structure also contained several pictures of the Emperor and Empress and a photograph of Russian and Japanese generals taken ensemble after the fall of Port Arthur. Elsewhere in Japan these pictures are usually found in Shinto shrines rather than in the little Buddhist *dō*.

We also visited the two temples of Kureko. One has a priest, the other not. Certain ceremonies still take place at the latter, however. It is a melancholy place, its old straw roof overgrown with plants. Inside we found the hand fire pump of Kureko, a few books of sutras and a Buddhist statue. The image and other woodwork had been painted, but most of the paint has peeled off from age and lack of care.

We were told that about ten years previ-

ously there had been a fire in which the school burned down as well as one of the temples. In its place a tin-roofed one was erected which is today the only active temple for many miles around. For memorial services a person from another settlement comes here ahead of time to tell the priest to read sutras, then returns home where a banquet for relatives is held. As might be expected in this isolated region the Buddhist priest does a little farming in addition to his priestly duties. Most of the people of Kureko belong to the Shinshū sect of Buddhism.

There is also a Shinto shrine, housing a mountain god, and a Shinto priest. The shrine is new, and like the recently rebuilt temple, it has a tin roof. The annual festival is held on the first of the eighth month, by lunar calendar.

Next we visited an aged man, seventy-seven years old, who used to be *shōya*, or headman, of Kureko, before the new governmental system replaced the feudal one in this region. When we called, we discovered him busy making a basketry bag (Fig. 8). He has a son who is postmaster of the post office in Kobaru.

Our host, the *kuchō*, told us that the *shōya* claims descent from the Heike and has an old sword—but shows it to no one. From the *kuchō's* manner of recounting this he evidently bears the old *shōya* no great love. The *kuchō* says that most people have old swords, but that the old *shōya* is the only man in Kureko who claims descent from the Heike.

The single shop of Kureko was our next stop. We found it in the care of a still older person—a woman of ninety-three. Her family is the same as that of our host's wife. A beautiful girl of fourteen waited on us. She said they sell four or five cans of pineapple a month, mostly to transients such as ourselves. *Sake* is also sold, and dried seaweed. There was one can of beef and a few bottles of beer in stock. Metal tool blades were also for sale; the farmers buy them and make their own handles of wood. The little shop sells neither tobacco nor salt; for these one must go to Miyazono.

Money expenses in Kureko are few, mostly

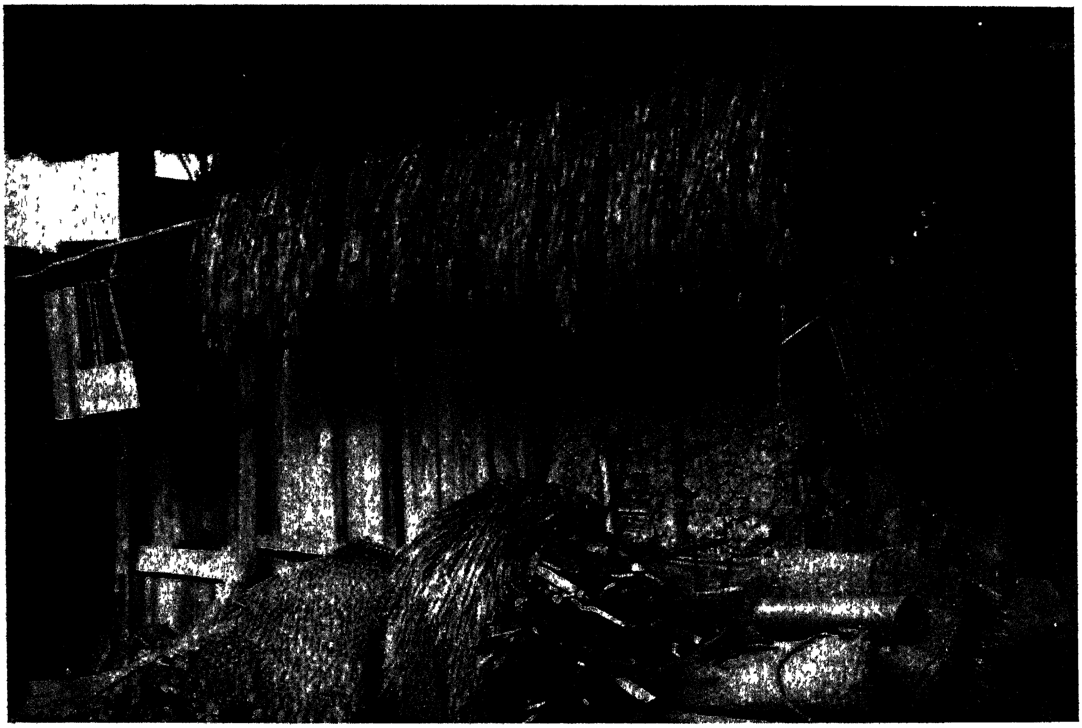


FIG. 7. FARM STORAGE UNDER THE EAVES OF A MOUNTAIN COTTAGE
SEED GRAIN AND VEGETABLES ARE HUNG UP TO DRY. NOTE ALSO THE BIRD CAGE, FIREWOOD, AND ODDMENTS.

for wine and clothes. All food is home-grown. Labor is exchanged. Cloth is purchased in Miyazono and made into garments by the women.

In the *kuchō's* house are many drums and some hats of cocks' feathers. These are for the Taiko Odori, or Drum Dance (Fig. 9), which is performed three times a year at Bon (the festival of the return of spirits of the dead in mid-July), on August 1 (the day of the Shinto Shrine celebration), and on the last day of autumn Higan (a Buddhist celebration of the autumn equinox). Both the *kuchō* and his son are dancers and members of the dancers' society. Any man may enter this society if he announces his intention at the beginning of the year, but once he has joined, he must perform dances for ever after.

People come to see the Drum Dance from as far away as Mizukami (a village outside Gokkanosho). The drum skins are made of the hide of the wild boar, imported from Nagano prefecture far to the north. They used to use local boar, but this is now extinct. Dances, of which there are many varieties, are performed in the schoolyard.

We began our walk to the next hamlet of Shiibaru amid immense and steep mountains checkered here and there with *koba* where the mountaineers eke out a living. The fields are on hillsides said to be at an incline of 45° or more. Being 2 or 3 miles distant from home is only half the difficulty of farming them; the steepness of the grade in getting to them is worse. Charcoal workers here send wood down hillsides and across ravines on wires.

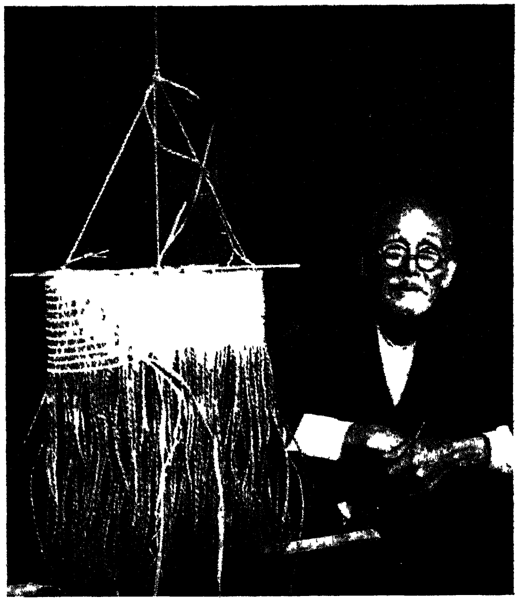


FIG. 8. VENERABLE EX–HEADMAN
MAKES FIBER BAGS, SMOKING A THREE-PUFF PIPE.

We soon met a man making a new clearing. He told us that a tenant such as himself pays as rent one-fifth of the produce of the *koba*

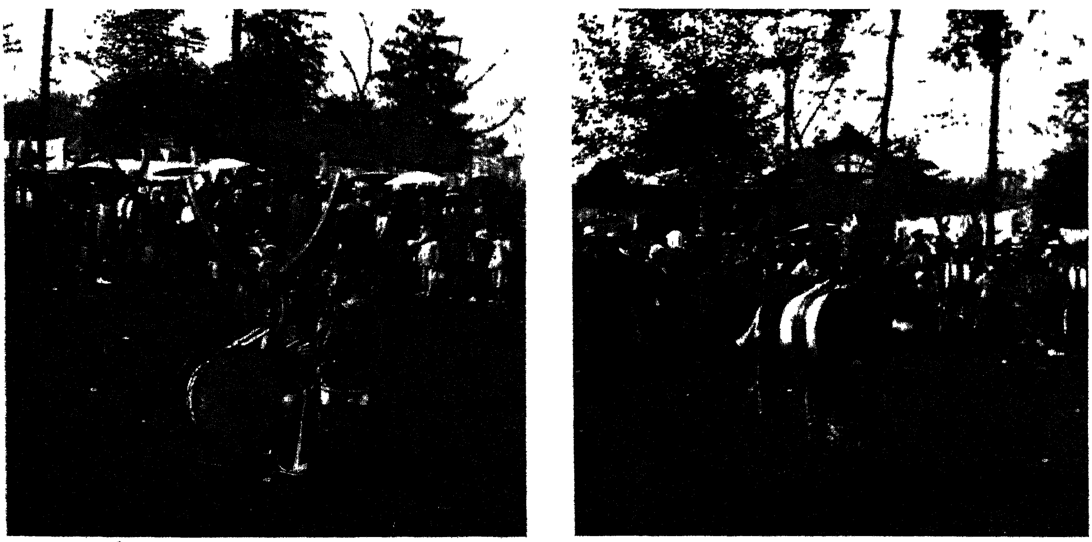


FIG. 9. THE DRUM DANCE, OR TAIKO ODORI
MEMBERS OF THE DRUM DANCE SOCIETY PRANCE BEFORE A CROWD AT A FESTIVAL SOUTH OF GOKKANOSHO.

he cultivates for three years and thereafter may work it free indefinitely. A good *koba* might last seven years. He also told us that our host and his wife of the night before both come from rich families.

Later we met a man from Nitao hamlet on his way to Kureko to tell the priest of a three-year memorial service for his mother. He will spend the night with the priest before returning to Nitao.

After four hours' walk we came to Shiibaru, a beautiful little hamlet of fifteen families (Figs. 10 and 11). Just outside the settlement itself we passed fields with more tea than the usual. Some bushes were scattered amid corn fields, but others were neatly arranged and evidently well cared for, much more so than the wild tea bushes used by the plains people of Kuma.

All the people of Shiibaru claim to be descended from the Heike—every man a *bushi*. The old *shōya's* house was a fine structure, larger and grander than anything in Suye. The house and outbuildings were on a large earth platform sustained by stone embankments. A *shōya's* house in Gokkanosho always stands out. The people here preserve old forms of politeness not found in ordinary rural districts—a part of their pride of ancestry. Even ordinary houses in Shiibaru have gardens of stunted trees, stone walls, and an air of ancient grandeur.

There are no shops in the hamlet and but one inn. We saw a tobacco sign, but no one was home at the house where it was hung. At the inn, really a private house which serves tea and cakes to travellers, we rested and talked with the mistress of the house over our refreshments. We were told that the chief products of the hamlet are tea and mushrooms. We were also told, probably as a boast, that people here often receive wives from big cities such as Osaka and Tokyo. If a man goes on a trip he may bring home a wife from such a large city.

The man of the inn showed us some *montake,* bamboo that has been stained by mold or in some other natural manner in the forest. He said that such bamboo is rare and that it occurs only in Gokkanosho. He sells it. He told us also that the hamlets of Shiibaru, Nitao, and Momigi were under the

FIG. 10. THE APPROACH TO THE HAMLET OF SHIIBARU
THE PATCHES ON THE MOUNTAINSIDE ARE FIELDS, OR *koba,* FROM WHICH THE INHABITANTS EKE A LIVING.

FIG. 11. A CLOSER VIEW OF SHIIBARU
COMPARE THESE NEAT ROOFS WITH THE VERDANT ROOF IN FIG. 4. EACH DISTRICT HAS ITS OWN ROOF TYPE.

Heike while Kureko and Hagi were under Sugawara. This might account for the lack of Heike descendants in Kureko.

Before we left, the woman told us that we might expect a long, steep incline a short distance from the hamlet. Soon we came to a stream of unusual beauty rushing under an old, rotten wooden bridge and on by some black, damp overhanging rocks. The noisy water itself was a mixture of color: white, blue, green, and in dark, deep places, black. Then we came to the sharp ascent. The woman did not exaggerate; it was long, it was rough, and it was steep.

The next hamlet, Kobaru, is a cluster of houses like Shiibaru. Here there is a school, a post office, and a shop. Because of bad water, we did not stop. A little farther on we came to a settlement consisting of one house, called Shimoyashiki (five miles to the east is one of two houses called Furuyashiki). Both these districts form part of Nitao hamlet.

The one house of Shimoyashiki was large and spacious. When we arrived, we found a manservant mending the paper screens. When we inquired concerning lodging for the night, he disappeared into the recesses of the house and soon returned with paper and a request for our names. These were given, and shortly thereafter we were shown to a hot bath in an elegant bathhouse.

The main house was on rather a grand scale; more so than any in Suye, though, unlike Suye, many of the rooms are not occupied. These vacant rooms have no straw mats laid down, but they are put down for guests.

For supper our rice was cooked, and we were given potato and seafish soup. I asked for a cucumber, and soon a small boy came in breathless and held out with his two hands a large and luscious cucumber. Then he rushed out. His polite manner of handing it to us was remarkable, symptomatic of the formal ways of Heike descendants. One young companion from Suye said jokingly that in Suye a boy would hand a cucumber with his foot.

Both before and after dinner, our host came to talk with us. His manners also were marked by polite formality. The dinner

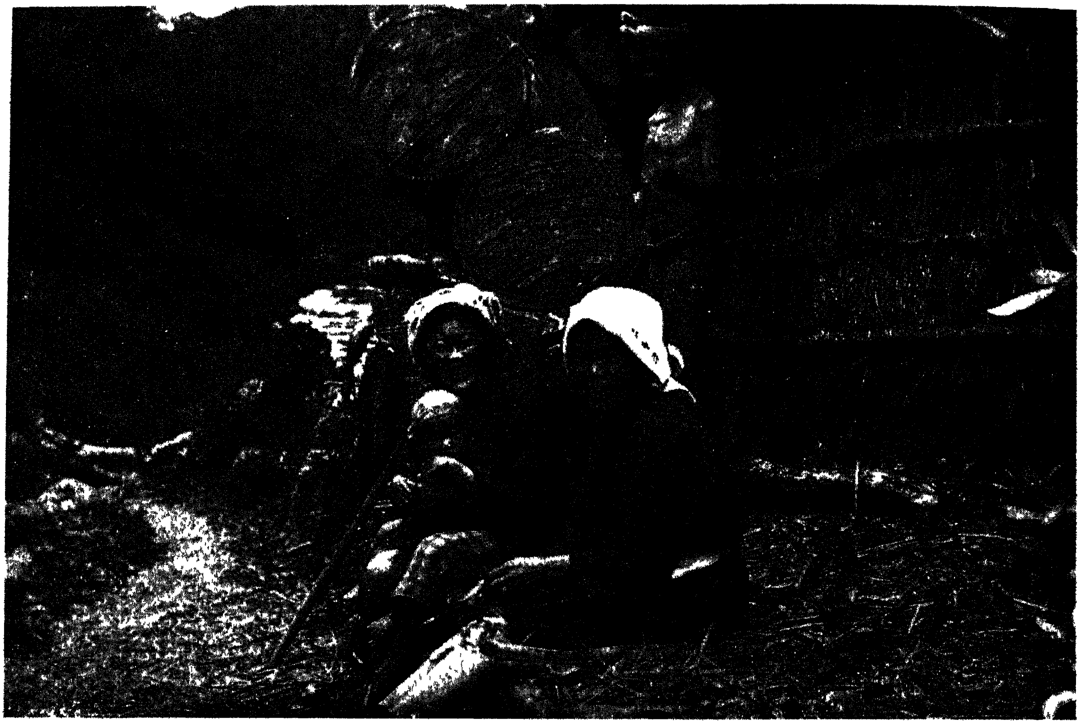


FIG. 12. CARRIERS OF WOOD AND CHARCOAL NEAR IWAOKU
PAID IN CASH, THEY BUY RICE, WHEREAS MOST FARMERS OF THE MOUNTAINS SUBSIST CHIEFLY ON MILLET.

itself was served to us by his wife. The family did not eat with us but in another room by the kitchen at the other end of the house.

We learned from our host, Mr. Zoza Sataro, that each hamlet of Gokkanosho has a council of men called *kukaigin* for administering local school affairs. People pay a tax for local school affairs of about one *yen* fifty in addition to a house tax of less than five *yen* (villages in the plains pay an average of twenty to thirty *yen*). There is in addition a special land tax for large landowners.

He told us also about the political organization of the area (he is himself a village councilor). His grandfather was head of the post office in Kobaru, his great grandfather a *shōya.* He is himself an adopted son. His wife is also from outside the family. The important thing is the house and the name; the individuals merely carry it on.

There is no true Shinto priest in Gokkanosho. Instead, one in Kakisako is hired once a year for the shrine festival. The one mentioned in Kureko, it seems, is not an orthodox one. There is, however, a Shinto shrine (*sonsha*) in each hamlet of Gokkanosho.

As he talked he held the small boy in his lap and eventually the child fell asleep. Other children occasionally peeked in but were reprimanded by their father. There was much more formality in this household than in that of the *kuchō* at Kureko.

In the morning, as at Kureko, we awoke to a cool mist, the sound of a mountain stream, and the view of high mountains.

After a breakfast of lukewarm rice, our hostess brought us rice balls wrapped in bamboo shoot sheaths to serve for our lunch. Taking our leave at nine o'clock, we walked fairly constantly for three hours through forests, along steep rocky hillsides with here and there a *koba,* those remarkable fields where people grow crops out of nothing.

When not far from Iwaoku, a settlement beyond old Gokkanosho, we met a family of carriers well loaded down with wood. They said they receive 35 *sen* for each sack of charcoal and 50 *sen* for each bundle of wood for tubs. They make one trip of about three miles a day (Fig. 12). With the money they buy rice and thus have a different diet from

the farmers of the mountains who eat only millet and wheat, both regarded as much inferior to rice. While the trip is comparatively short, it is very hilly and the loads extremely heavy.

Soon we met other carriers and hikers and so could tell we were coming closer to civilization. Finally we came to the top of a high ridge and there, suddenly, we came upon an immense panorama of hills and valleys in the foreground with the sea visible in the far distance.

As we descended the path on the other side and eventually approached Iwaoku, the hillsides were broken into terraces, the high ones for sweet potatoes, millet, etc., the lower ones for rice. Tiger lilies grew near the potato patches, the root being considered good to eat.

The little village of Iwaoku is where the road to Yatsushiro town begins. Here are shops, rice wine, and various evidences of a typical village. Here many people from Gokkanosho come for supplies and from here wagoners take lumber down to the towns. We saw several wagoners busy drinking.

As there was no bus here, we had to walk on a couple of miles farther. Finally we came to Kayaba where there is a school. By the side of the road at the entrance were images of Jizō, Daiishi, and a Sarutahiko stone all in a row, so the place was well protected.

But Kayaba, like Iwoaka, had no bus service. We walked on again, feeling very tired and finally came to Futae where at last we found a bus station and what was more, a bus was due in twenty minutes. So we sat down to a late and hasty lunch.

The bus proved to be a 1931 Ford touring car. We, and one other man climbed in. The bus took us to Arisa, north of Yatsushiro, just in time for the train to Hitoyoshi and thence back to Suye. And so we returned to our home in the ordinary but familiar rice village of Suye Mura. When we met people on the road the next day, they bowed, saying, "You have had a long trip, are you not tired?"

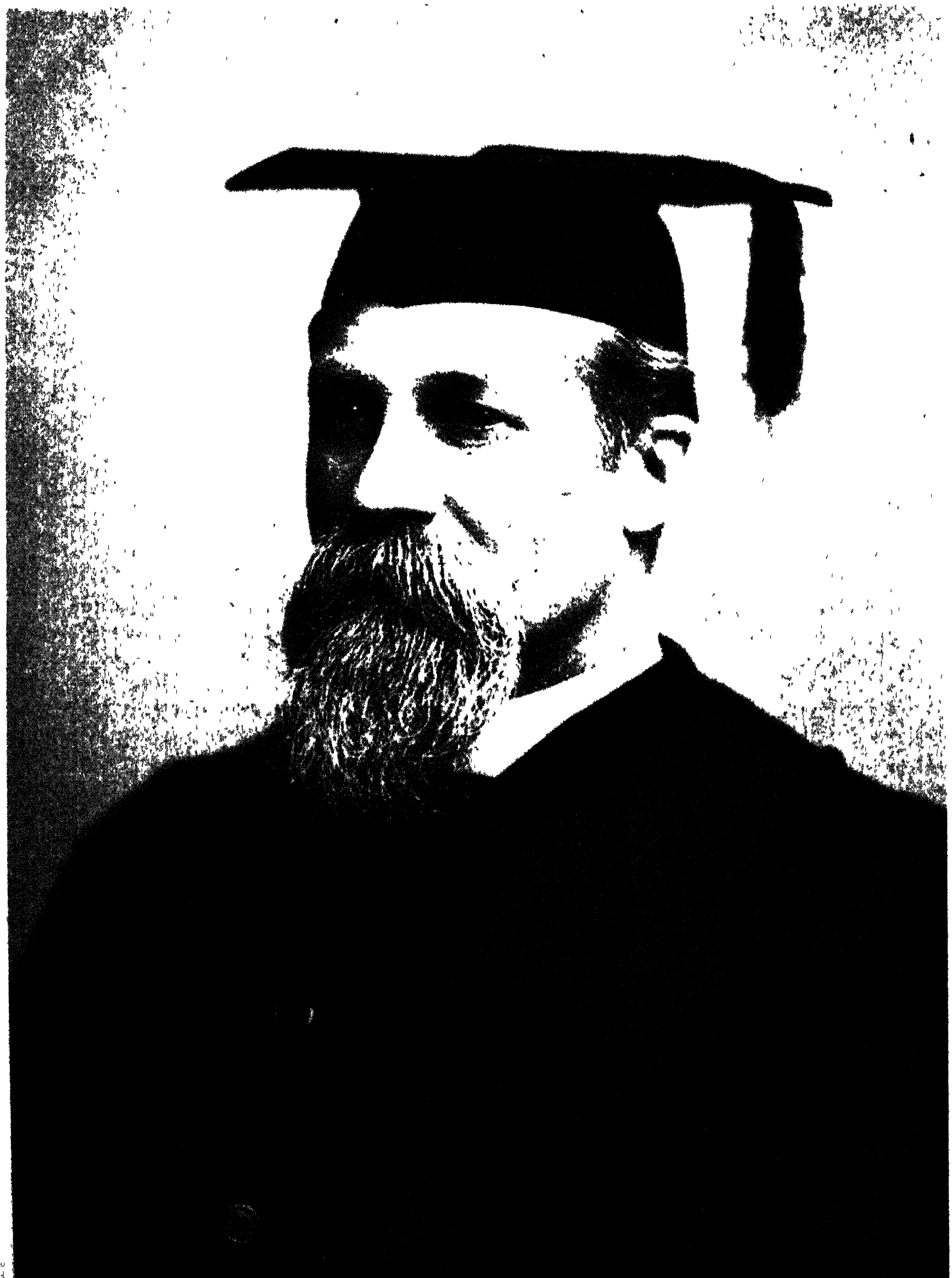
In conclusion I should like to make a few general remarks about this interesting old region of Japan. One striking thing about the settlement is the number of fine dwellings. Another is the apparent similarity of daily life here with that of old Japan. However, we found no examples of the big family households of several brothers and their wives and children under one roof as some people had reported to us before our trip through Gokkanosho.

There are certain customs in striking contrast to the relatively nearby area of Kuma, such as relatives instead of neighbors acting as pallbearers at a funeral. The economic life is also rather different from ordinary Japanese villages. The communities are pretty well self-sustaining, depending for food on millet and potatoes instead of rice, and the cash income is from lumber and mushrooms instead of silk and rice. Whereas rice sometimes still serves as a medium of exchange in certain intravillage affairs in the plains, in Gokkanosho the *azuki* bean is used.

Electricity and gas engines, common in rural Japan today, are quite absent from Gokkanosho.

There is considerable variety between the hamlets. In Kureko, for instance, the people do not claim Heike descent, and the houses are for the most part unimposing and scattered geographically. All marriages are said to take place within the village. Shiibaru, on the other hand, claims noble descent from the Heike, wives frequently come from outside, and the beautiful houses and gardens form a compact cluster. The Kureko *kuchō* says that the people of Hagi do much drinking, those of Kureko little. If true, why? A profitable social study could be made of life in these various mountain settlements.

Gokkanosho is still an isolated region, an area of old folk culture. Since my visit I have read that there are plans to build over a period of five years a road through the region for carrying out timber. Since the war began this may have been completed, thus removing some of the isolation of the mountain hamlets. The basic economy and general way of life, however, doubtless remain much the same today as they were six years ago.



T. C. CHAMBERLIN, 1843–1928

THE METHOD OF MULTIPLE WORKING HYPOTHESES*

By T. C. CHAMBERLIN

THERE are two fundamental modes of study. The one is an attempt to follow by close imitation the processes of previous thinkers and to acquire the results of their investigations by memorizing. It is study of a merely secondary, imitative, or acquisitive nature. In the other mode the effort is to think independently, or at least individually. It is primary or creative study. The endeavor is to discover new truth or to make a new combination of truth or at least to develop by one's own effort an individualized assemblage of truth. The endeavor is to think for one's self, whether the thinking lies wholly in the fields of previous thought or not. It is not necessary to this mode of study that the subject matter should be new. Old material may be reworked. But it is essential that the process of thought and its results be individual and independent, not the mere following of previous lines of thought ending in predetermined results. The demonstration of a problem in Euclid precisely as laid down is an illustration of the former, the demonstration of the same proposition by a method of one's own or in a manner distinctively individual is an illustration of the latter, both lying entirely within the realm of the known and old.

Creative study, however, finds its largest application in those subjects in which, while much is known, more remains to be learned. The geological field is pre-eminently full of such subjects; indeed, it presents few of any other class. There is probably no field of thought which is not sufficiently rich in such subjects to give full play to investigative modes of study.

Three phases of mental procedure have been prominent in the history of intellectual evolution thus far. What additional phases may be in store for us in the evolutions of the future it may not be prudent to attempt to forecast. These three phases may be styled "the method of the ruling theory," "the method of the working hypothesis," and "the method of multiple working hypotheses."

In the earlier days of intellectual development the sphere of knowledge was limited and could be brought much more nearly than now within the compass of a single individual. As a natural result those who then assumed to be wise men, or aspired to be thought so, felt the need of knowing, or at least seeming to know, all that was known, as a justification of their claims. So also as a natural counterpart there grew up an expectancy on the part of the multitude that the wise and the learned would explain whatever new thing presented itself. Thus pride and ambition on the one side and expectancy on the other joined hands in developing the putative all-wise man whose knowledge boxed the compass and whose acumen found an explanation for every new puzzle which presented itself. Although the pretended compassing of the entire horizon of knowledge has long since become an abandoned affectation, it has left its representatives in certain intellectual predilections. As in the earlier days, so still, it is a too frequent habit to hastily conjure up an explanation for every new phenomenon that presents itself. Interpretation leaves its proper place at the end of the intellectual procession and rushes to the forefront. Too often a theory is promptly

* Professor T. C. Chamberlin of the University of Chicago, who died in 1928, was a famous geologist and a former president of the American Association for the Advancement of Science. He was noted for his rigorous application of the scientific method. In 1897 he published in the *Journal of Geology* (vol. 5, pp. 837–848) the paper that is here reprinted with permission of the University of Chicago Press. Because the demand for it continued through the years, it was reprinted in 1931 in the *Journal of Geology* (vol. 39, pp. 155–165). Such evidence of the importance of this essay to geologists suggested that it should be made available to other scientists, all of whom should be acquainted with "The Method of Multiple Working Hypotheses." Grateful acknowledgment is made to Professor R. T. Chamberlin for making arrangements for the reprinting of this article and for supplying the portrait of his father, at age 40, shown on the opposite page.—Eds.

born and evidence hunted up to fit it afterward. Laudable as the effort at explanation is in its proper place, it is an almost certain source of confusion and error when it runs before a serious inquiry into the phenomenon itself. A strenuous endeavor to find out precisely what the phenomenon really is should take the lead and crowd back the question, commendable at a later stage, "How came this so?" First the full facts, then the interpretation thereof, is the normal order.

The habit of precipitate explanation leads rapidly on to the birth of general theories.[1] When once an explanation or special theory has been offered for a given phenomenon, self-consistency prompts to the offering of the same explanation or theory for like phenomena when they present themselves, and there is soon developed a general theory explanatory of a large class of phenomena similar to the original one. In support of the general theory there may not be any further evidence or investigation than was involved in the first hasty conclusion. But the repetition of its application to new phenomena, though of the same kind, leads the mind insidiously into the delusion that the theory has been strengthened by additional facts. A thousand applications of the supposed principle of levity to the explanation of ascending bodies brought no increase of evidence that it was the true theory of the phenomena; but it doubtless created the impression in the minds of ancient physical philosophers that it did, for so many additional facts seemed to harmonize with it.

For a time these hastily born theories are likely to be held in a tentative way with some measure of candor or at least some self-illusion of candor. With this tentative spirit and measurable candor, the mind satisfies its moral sense and deceives itself with the thought that it is proceeding cautiously and impartially toward the goal of ultimate truth. It fails to recognize that no amount of provisional holding of a theory, no amount of application of the theory, so long as the study lacks in incisiveness and exhaustiveness, justifies an ultimate conviction. It is not the slowness with which conclusions are arrived at that should give satisfaction to the moral sense, but the precision, the completeness and the impartiality of the investigation.

It is in this tentative stage that the affections enter with their blinding influence. Love was long since discerned to be blind, and what is true in the personal realm is measurably true in the intellectual realm. Important as the intellectual affections are as stimuli and as rewards, they are nevertheless dangerous factors in research. All too often they put under strain the integrity of the intellectual processes. The moment one has offered an original explanation for a phenomenon which seems satisfactory, that moment affection for his intellectual child springs into existence; and as the explanation grows into a definite theory, his parental affections cluster about his offspring and it grows more and more dear to him. While he persuades himself that he holds it still as tentative, it is none the less lovingly tentative and not impartially and indifferently tentative. So soon as this parental affection takes possession of the mind, there is apt to be a rapid passage to the unreserved adoption of the theory. There is then imminent danger of an unconscious selection and of a magnifying of phenomena that fall into harmony with the theory and support it and an unconscious neglect of phenomena that fail of coincidence. The mind lingers with pleasure upon the facts that fall happily into the embrace of the theory, and feels a natural coldness toward those that assume a refractory attitude. Instinctively, there is a special searching-out of phenomena that support it, for the mind is led by its desires. There springs up also unwittingly a pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory. When these biasing tendencies set in, the mind rapidly degenerates into the partiality of paternalism. The search for facts, the observation of phenomena, and their interpretation are all dominated by affection for the favored theory until it appears to its

[1] I use the term "theory" here instead of hypothesis because the latter is associated with a better controlled and more circumspect habit of the mind. This restrained habit leads to the use of the less assertive term "hypothesis," while the mind in the habit here sketched more often believes itself to have reached the higher ground of a theory and more often employs the term "theory." Historically also, I believe the word "theory" was the term commonly used at the time this method was predominant.

author or its advocate to have been overwhelmingly established. The theory then rapidly rises to a position of control in the processes of the mind and observation; induction and interpretation are guided by it. From an unduly favored child it readily grows to be a master and leads its author whithersoever it will. The subsequent history of that mind in respect to that theme is but the progressive dominance of a ruling idea. Briefly summed up, the evolution is this: a premature explanation passes first into a tentative theory, then into an adopted theory, and lastly into a ruling theory.

When this last stage has been reached, unless the theory happens perchance to be the true one, all hope of the best results is gone. To be sure, truth may be brought forth by an investigator dominated by a false ruling idea. His very errors may indeed stimulate investigation on the part of others. But the condition is scarcely the less unfortunate.

As previously implied, the method of the ruling theory occupied a chief place during the infancy of investigation. It is an expression of a more or less infantile condition of the mind. I believe it is an accepted generalization that in the earlier stages of development the feelings and impulses are relatively stronger than in later stages.

Unfortunately the method did not wholly pass away with the infancy of investigation. It has lingered on, and reappears in not a few individual instances at the present time. It finds illustration in quarters where its dominance is quite unsuspected by those most concerned.

The defects of the method are obvious and its errors grave. If one were to name the central psychological fault, it might be stated as the admission of intellectual affection to the place that should be dominated by impartial, intellectual rectitude alone.

So long as intellectual interest dealt chiefly with the intangible, so long it was possible for this habit of thought to survive and to maintain its dominance, because the phenomena themselves, being largely subjective, were plastic in the hands of the ruling idea; but so soon as investigation turned itself earnestly to an inquiry into natural phenomena whose manifestations are tangible, whose properties are inflexible, and whose laws are rigorous, the defects of the method became manifest and an effort at reformation ensued. The first great endeavor was repressive. The advocates of reform insisted that theorizing should be restrained and the simple determination of facts should take its place. The effort was to make scientific study statistical instead of causal. Because theorizing in narrow lines had led to manifest evils, theorizing was to be condemned. The reformation urged was not the proper control and utilization of theoretical effort but its suppression. We do not need to go backward more than a very few decades to find ourselves in the midst of this attempted reformation. Its weakness lay in its narrowness and its restrictiveness. There is no nobler aspiration of the human intellect than the desire to compass the causes of things. The disposition to find explanations and to develop theories is laudable in itself. It is only its ill-placed use and its abuse that are reprehensible. The vitality of study quickly disappears when the object sought is a mere collocation of unmeaning facts.

The inefficiency of this simply repressive reformation becoming apparent, improvement was sought in the method of the working hypothesis. This has been affirmed to be *the* scientific method. But it is rash to assume that any method is *the* method, at least that it is the ultimate method. The working hypothesis differs from the ruling theory in that it is used as a means of determining facts rather than as a proposition to be established. It has for its chief function the suggestion and guidance of lines of inquiry—the inquiry being made, not for the sake of the hypothesis, but for the sake of the facts and their elucidation. The hypothesis is a mode rather than an end. Under the ruling theory, the stimulus is directed to the finding of facts for the support of the theory. Under the working hypothesis, the facts are sought for the purpose of ultimate induction and demonstration, the hypothesis being but a means for the more ready development of facts and their relations.

It will be observed that the distinction is not such as to prevent a working hypothesis from gliding with the utmost ease into a ruling theory. Affection may as easily cling

about a beloved intellectual child when named a "hypothesis" as if named a "theory," and its establishment in the one guise may become a ruling passion very much as in the other. The historical antecedents and the moral atmosphere associated with the working hypothesis lend some good influence, however, toward the preservation of its integrity.

Conscientiously followed, the method of the working hypothesis is an incalculable advance upon the method of the ruling theory, but it has some serious defects. One of these takes concrete form, as just noted, in the ease with which the hypothesis becomes a controlling idea. To avoid this grave danger, the method of multiple working hypotheses is urged. It differs from the simple working hypothesis in that it distributes the effort and divides the affections. It is thus in some measure protected against the radical defect of the two other methods. In developing the multiple hypotheses, the effort is to bring up into view every rational explanation of the phenomenon in hand and to develop every tenable hypothesis relative to its nature, cause, or origin, and to give to all of these as impartially as possible a working form and a due place in the investigation. The investigator thus becomes the parent of a family of hypotheses; and by his parental relations to all is morally forbidden to fasten his affections unduly upon any one. In the very nature of the case, the chief danger that springs from affection is counteracted. Where some of the hypotheses have been already proposed and used, while others are the investigator's own creation, a natural difficulty arises; but the right use of the method requires the impartial adoption of all alike into the working family. The investigator thus at the outset puts himself in cordial sympathy and in parental relations (of adoption, if not of authorship) with every hypothesis that is at all applicable to the case under investigation. Having thus neutralized, so far as may be, the partialities of his emotional nature, he proceeds with a certain natural and enforced erectness of mental attitude to the inquiry, knowing well that some of his intellectual children (by birth or adoption) must needs perish before maturity, but yet with the hope that several of them may survive the ordeal of crucial research, since it often proves in the end that several agencies were conjoined in the production of the phenomena. Honors must often be divided between hypotheses. One of the superiorities of multiple hypotheses as a working mode lies just here. In following a single hypothesis, the mind is biased by the presumptions of its method toward a single explanatory conception. But an adequate explanation often involves the co-ordination of several causes. This is especially true when the research deals with a class of complicated phenomena naturally associated but not necessarily of the same origin and nature, as, for example, the Basement complex or the Pleistocene drift. Several agencies may not only participate but their proportions and importance may vary from instance to instance in the same field. The true explanation is therefore necessarily complex, and the elements of the complex are constantly varying. Such distributive explanations of phenomena are especially contemplated and encouraged by the method of multiple hypotheses and constitute one of its chief merits. For many reasons we are prone to refer phenomena to a single cause. It naturally follows that when we find an effective agency present, we are predisposed to be satisfied therewith. We are thus easily led to stop short of full results, sometimes short of the chief factors. The factor we find may not even be the dominant one, much less the full complement of agencies engaged in the accomplishment of the total phenomena under inquiry. The mooted question of the origin of the Great Lake basins may serve as an illustration. Several hypotheses have been urged by as many different students of the problem as the cause of these great excavations. All of these have been pressed with great force and with an admirable array of facts. Up to a certain point we are compelled to go with each advocate. It is practically demonstrable that these basins were river valleys antecedent to the glacial incursion. It is equally demonstrable that there was a blocking-up of outlets. We must conclude then that the present basins owe their origin in part to the pre-existence of river valleys and to the blocking-up of their outlets by drift. That there is a temptation to rest here, the history of the question shows. But

on the other hand, it is demonstrable that these basins were occupied by great lobes of ice and were important channels of glacial movement. The leeward drift shows much material derived from their bottoms. We cannot therefore refuse assent to the doctrine that the basins owe something to glacial excavation. Still again it has been urged that the earth's crust beneath these basins was flexed downward by the weight of the ice load and contracted by its low temperature and that the basins owe something to crustal deformation. This third cause tallies with certain features not readily explained by the others. And still it is doubtful whether all these combined constitute an adequate explanation of the phenomena. Certain it is, at least, that the measure of participation of each must be determined before a satisfactory elucidation can be reached. The full solution therefore involves not only the recognition of multiple participation but an estimate of the measure and mode of each participation. For this the simultaneous use of a full staff of working hypotheses is demanded. The method of the single working hypothesis or the predominant working hypothesis is incompetent.

In practice it is not always possible to give all hypotheses like places, nor does the method contemplate precisely equable treatment. In forming specific plans for field, office, or laboratory work, it may often be necessary to follow the lines of inquiry suggested by some one hypothesis rather than those of another. The favored hypothesis may derive some advantage therefrom or go to an earlier death, as the case may be, but this is rather a matter of executive detail than of principle.

A special merit of the use of a full staff of hypotheses co-ordinately is that in the very nature of the case it invites thoroughness. The value of a working hypothesis lies largely in the significance it gives to phenomena which might otherwise be meaningless and in the new lines of inquiry which spring from the suggestions called forth by the significance thus disclosed. Facts that are trivial in themselves are brought forth into importance by the revelation of their bearings upon the hypothesis and the elucidation sought through the hypothesis. The phenomenal influence which the Darwinian hypothesis has exerted upon the investigations of the past two decades is a monumental illustration. But while a single working hypothesis may lead investigation very effectively along a given line, it may in that very fact invite the neglect of other lines equally important. Very many biologists would doubtless be disposed today to cite the hypothesis of natural selection, extraordinary as its influence for good has been, as an illustration of this. While inquiry is thus promoted in certain quarters, the lack of balance and completeness gives unsymmetrical and imperfect results. But if, on the contrary, all rational hypotheses bearing on a subject are worked co-ordinately, thoroughness, equipoise, and symmetry are the presumptive results in the very nature of the case.

In the use of the multiple method, the reaction of one hypothesis upon another tends to amplify the recognized scope of each. Every hypothesis is quite sure to call forth into clear recognition new or neglected aspects of the phenomena in its own interests, but ofttimes these are found to be important contributions to the full deployment of other hypotheses. The eloquent expositions of "prophetic" characters at the hands of Agassiz were profoundly suggestive and helpful in the explication of "undifferentiated" types in the hand of the evolutionary theory.

So also the mutual conflicts of hypotheses whet the discriminative edge of each. The keenness of the analytic process advocates the closeness of differentiating criteria, and the sharpness of discrimination is promoted by the co-ordinate working of several competitive hypotheses.

Fertility in processes is also a natural sequence. Each hypothesis suggests its own criteria, its own means of proof, its own method of developing the truth; and if a group of hypotheses encompass the subject on all sides, the total outcome of means and of methods is full and rich.

The loyal pursuit of the method for a period of years leads to certain distinctive habits of mind which deserve more than the passing notice which alone can be given them here. As a factor in education, the disciplinary value of the method is one of prime importance. When faithfully followed for a sufficient time, it develops a mode of thought

of its own kind which may be designated "the habit of parallel thought," or "of complex thought." It is contradistinguished from the linear order of thought which is necessarily cultivated in language and mathematics because their modes are linear and successive. The procedure is complex and largely simultaneously complex. The mind appears to become possessed of the power of simultaneous vision from different points of view. The power of viewing phenomena analytically and synthetically at the same time appears to be gained. It is not altogether unlike the intellectual procedure in the study of a landscape. From every quarter of the broad area of the landscape there come into the mind myriads of lines of potential intelligence which are received and co-ordinated simultaneously, producing a complex impression which is recorded and studied directly in its complexity. If the landscape is to be delineated in language, it must be taken part by part in linear succession.

Over against the great value of this power of thinking in complexes there is an unavoidable disadvantage. No good thing is without its drawbacks. It is obvious, upon studious consideration, that a complex or parallel method of thought cannot be rendered into verbal expression directly and immediately as it takes place. We cannot put into words more than a single line of thought at the same time, and even in that the order of expression must be conformed to the idiosyncrasies of the language. Moreover, the rate must be incalculably slower than the mental process. When the habit of complex or parallel thought is not highly developed, there is usually a leading line of thought to which the others are subordinate. Following this leading line the difficulty of expression does not rise to serious proportions. But when the method of simultaneous mental action along different lines is so highly developed that the thoughts running in different channels are nearly equivalent, there is an obvious embarrassment in making a selection for verbal expression, and there arises a disinclination to make the attempt. Furthermore, the impossibility of expressing the mental operation in words leads to their disuse in the silent processes of thought; and hence words and thoughts lose that close association which they are accustomed to maintain with those whose silent as well as spoken thoughts predominantly run in linear verbal courses. There is therefore a certain predisposition on the part of the practitioner of this method to taciturnity. The remedy obviously lies in co-ordinate literary work.

An infelicity also seems to attend the use of the method with young students. It is far easier, and apparently in general more interesting, for those of limited training and maturity to accept a simple interpretation or a single theory and to give it wide application, than to recognize several concurrent factors and to evaluate these as the true elucidation often requires. Recalling again for illustration the problem of the Great Lake basins, it is more to the immature taste to be taught that these were scooped out by the mighty power of the great glaciers than to be urged to conceive of three or more great agencies working successively in part and simultaneously in part and to endeavor to estimate the fraction of the total results which was accomplished by each of these agencies. The complex and the quantitative do not fascinate the young student as they do the veteran investigator.

The studies of the geologist are peculiarly complex. It is rare that his problem is a simple unitary phenomenon explicable by a single simple cause. Even when it happens to be so in a given instance, or at a given stage of work, the subject is quite sure, if pursued broadly, to grade into some complication or undergo some transition. He must therefore ever be on the alert for mutations and for the insidious entrance of new factors. If, therefore, there are any advantages in any field in being armed with a full panoply of working hypotheses and in habitually employing them, it is doubtless the field of the geologist.

WHEN AMERICAN SEASONS BEGIN

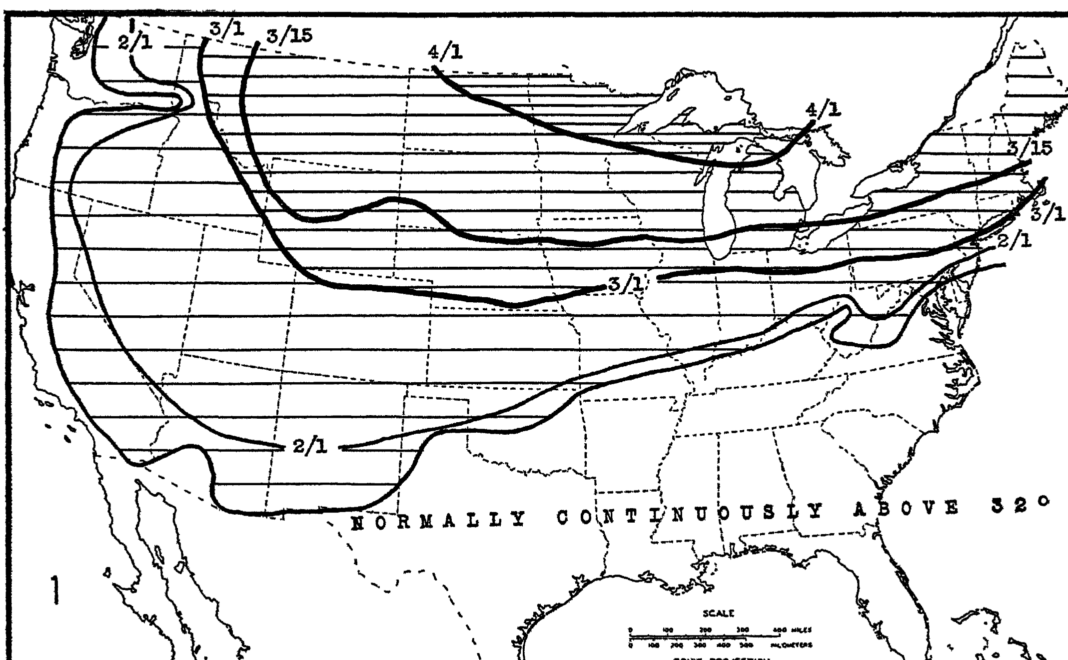
By STEPHEN S. VISHER

THE four chief seasons are popularly announced as commencing with dates of astronomic origin: spring with the vernal equinox, summer with the summer solstice, winter with the shortest day in the year, the winter solstice. But despite the convenience of such preciseness, the fact is that the seasons do not commence on those days in more than a small part of the country. Moreover, the climatic diversity is so great within the United States that the seasons which do occur are not everywhere comparable. Indeed much of the country has six rather than four seasons; two types of summer and two types of winter can readily be recognized on the basis of temperatures alone. In addition, there are seasonal contrasts in the amount and type of precipitation. For example, the wet season and the dry one are more distinct and significant on much of the Pacific Coast than are seasons based on temperatures.

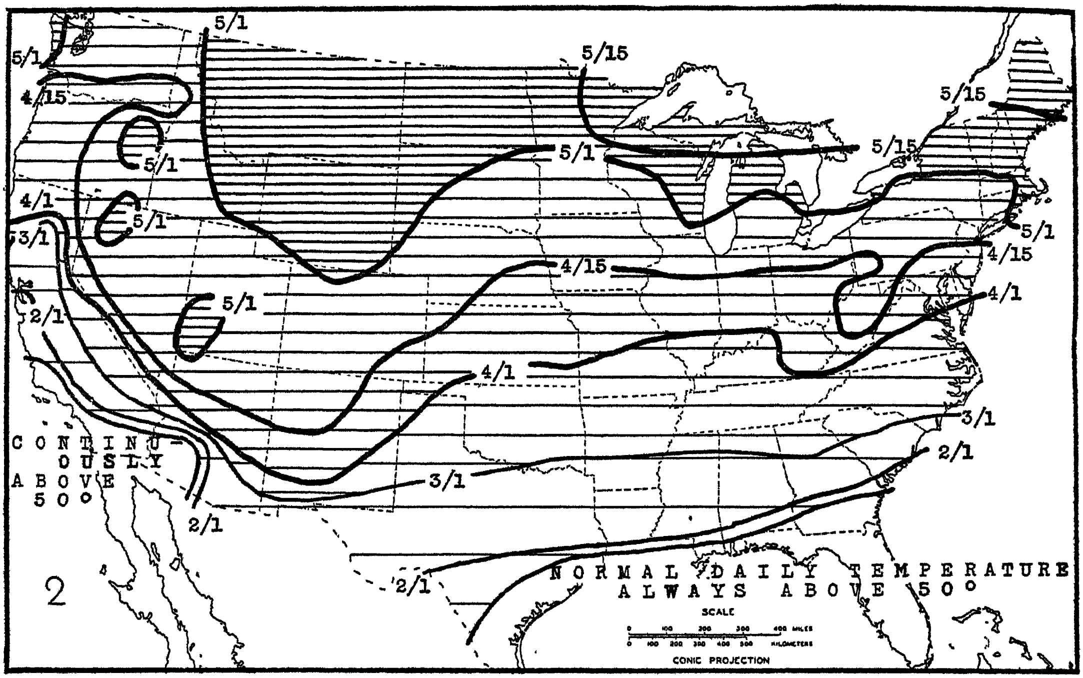
The present article presents nine original maps showing the dates of the beginning of various temperature seasons. The data upon which they are based are the official computations of the daily normal temperatures, the average of day and night, for a 46-year period for 160 well-distributed Weather Bureau Stations (*Monthly Weather Review,* Supplement No. 25).

The temperature limits selected to indicate the dates of the beginning of the seasons are those which seem appropriate, according to common opinion. However, as agreement is incomplete, alternative limits are presented in some instances.

When does spring come? According to one concept, it comes when winter ends, and as any period that has an average of day and night temperature below freezing surely is winter, spring can be said to commence when the daily normal temperature rises above 32° F. Map 1 shows that on this basis spring comes about February 1 along a line extending from Washington, D. C., to central New

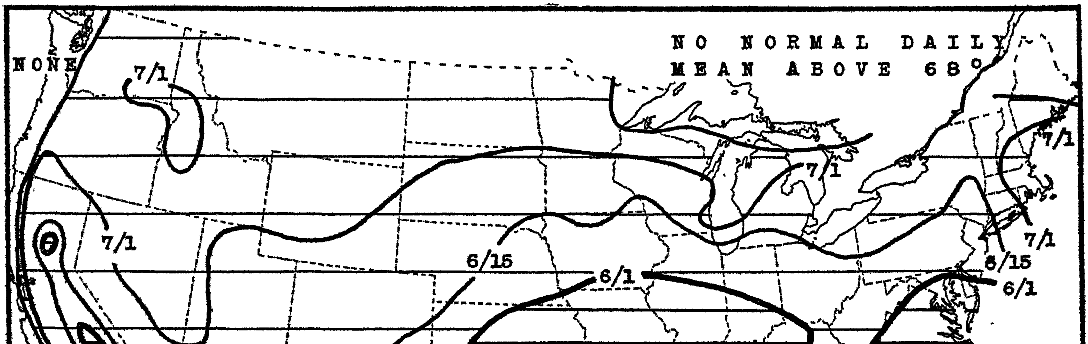


MAP 1. SPRING BEGINS (DATES WHEN DAILY NORMALS RISE ABOVE 32° F.)

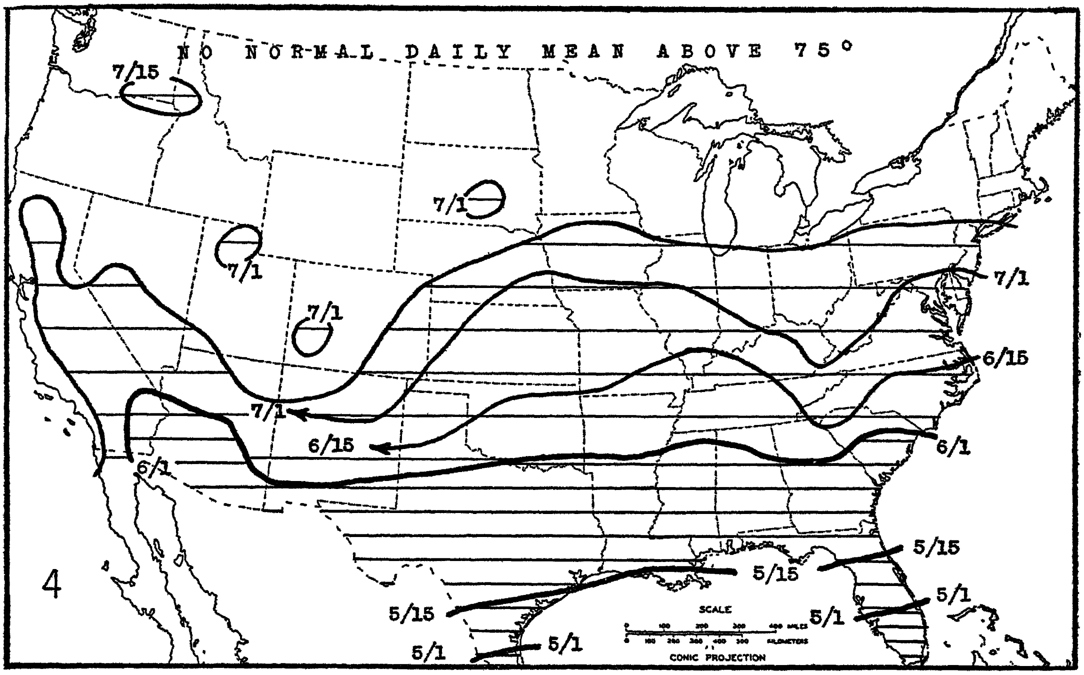


MAP 2. MILD SPRING BEGINS (DATES WHEN DAILY NORMALS RISE ABOVE 50° F.)

Mexico. It comes about March 1 along a line extending from Boston and New York almost due west to northern Colorado. It commences about April 1 in northern Michigan and northern North Dakota. In the South and near the Pacific Ocean, no daily normal is below freezing, and hence winter temperatures normally are lacking, although they



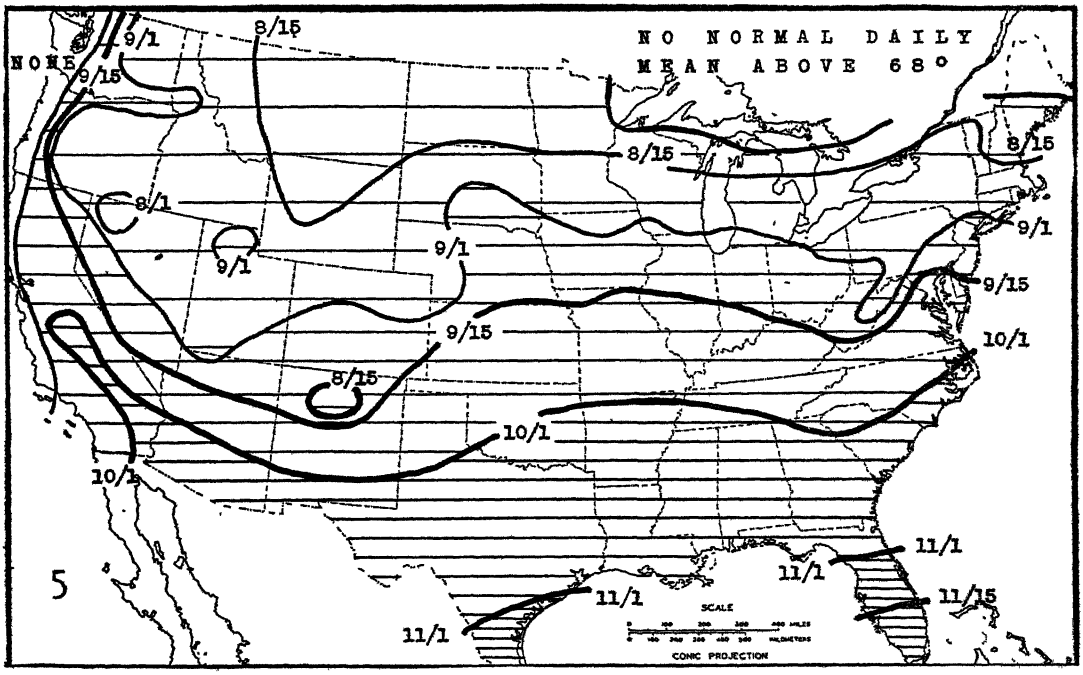
MAP 3. SUMMER BEGINS (DATES WHEN DAILY NORMALS REACH 68° F.)



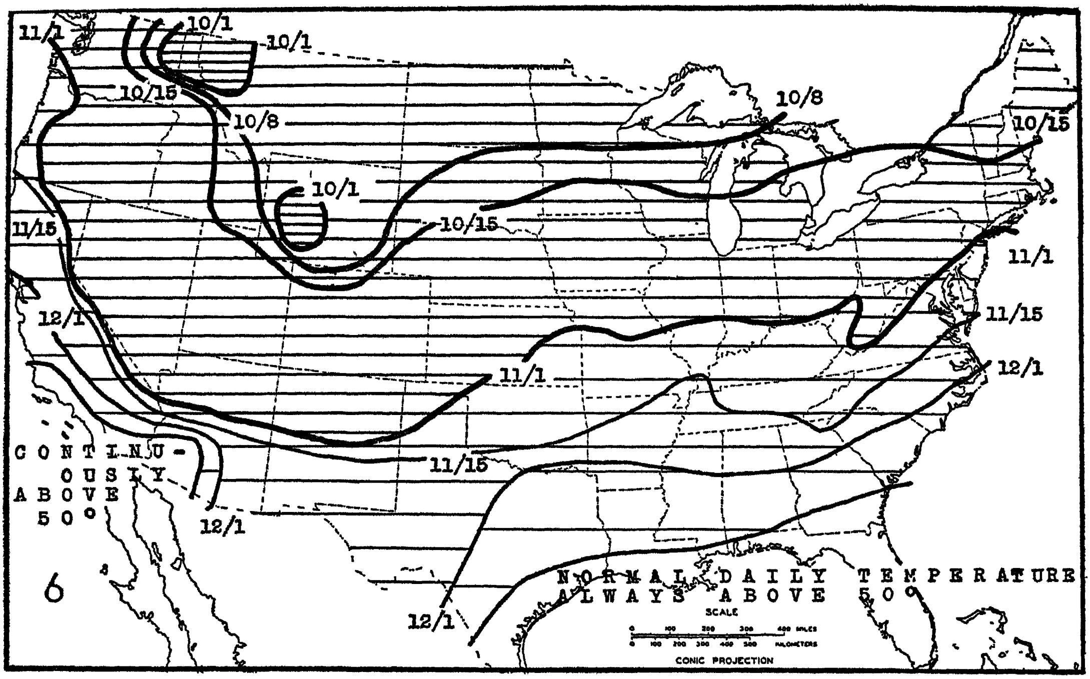
MAP 4. HOT SUMMER BEGINS (DATES WHEN DAILY NORMALS REACH 75° F.)

occur in occasional cold spells. Thus for those sections the beginning of spring as here defined is not indicated on this map.

When the average temperature of day and night together rises slightly above the freezing point, spring has barely commenced. A daily normal temperature of 50° is much more comfortable. Map 2 shows the dates



MAP 5. INDIAN SUMMER BEGINS (DATES WHEN DAILY NORMALS FALL BELOW 68° F.)



MAP 6. COOL FALL BEGINS (DATES WHEN DAILY NORMALS FALL BELOW 50° F.)

when 50° usually is attained. The arrival dates of this degree of warmth correspond more truly with the popular concept of the coming of spring than those shown in Map 1. Map 2 shows that on this basis mild spring temperatures usually commence about February 1 near the Gulf of Mexico and in southwestern California, about April 7 at Washington, D. C., and in central Illinois, and on May 1 or later in the northern states.

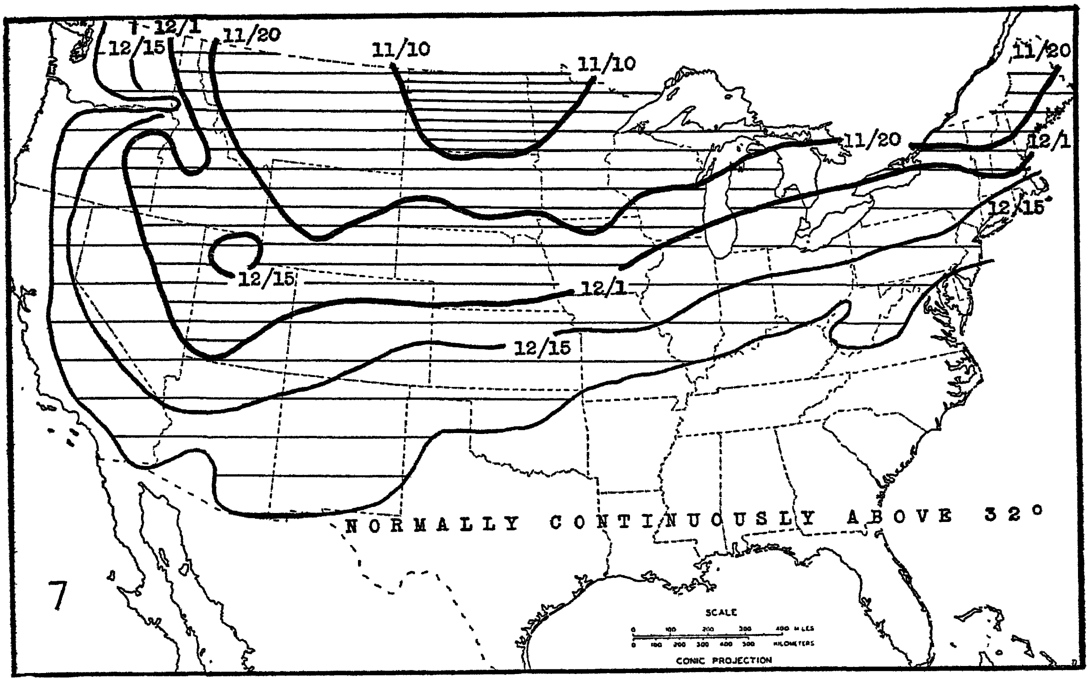
The conventional summer temperature begins with 68°. Map 3 shows that daily normals of 68° prevail even in March in southern Florida, and in April in a rather wide southern zone. They do not extend as far north as Washington, D. C., and central Illinois, however, until June. They never occur close to the Pacific Ocean and Lake Superior or upon the higher mountains.

Although 68° is always called a summer temperature, it represents a fairly mild sort of summer. Daily normals above 75° occur in more than half of the country. The normal dates of arrival of this hot summer condition, shown in Map 4, supplements Map 3 significantly. An average temperature of day and night together of 75° is about 10° above that optimum for human activity, according to extended studies by Ellsworth Huntington and several other investigators. This depressing heat is normally attained, according to Map 4, before June 1 in much of the South and during June in a zone some 400 miles wide extending from New Jersey and North Carolina to the Great Plains. Such high normals are almost lacking, however, in the northern part of the country.

Indian summer comes during the period following summer when the daily normal temperatures are between 68° and 50°. Map 5 shows that regular summer temperatures normally cease by September in the North and during October in the South. Thus Indian summer may be said to commence on the dates shown in Map 5.

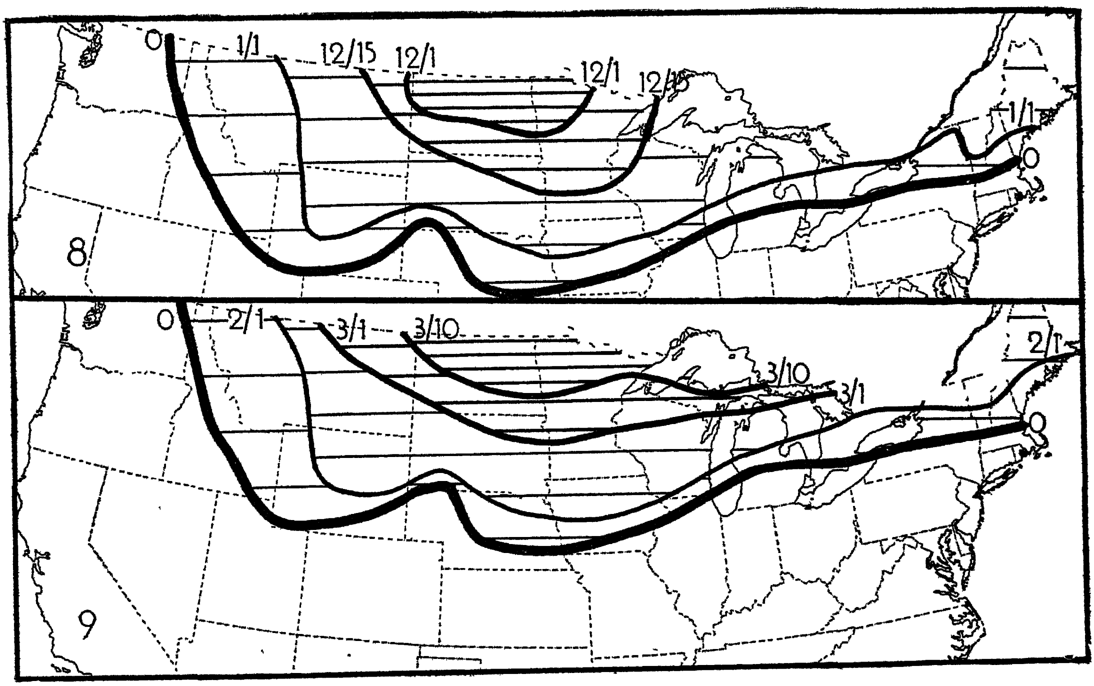
If autumn is the period during which daily normals are between 50° and 32°, it commences in October in the North, in November in the middle zone, and in December in a southern belt. Close to the Gulf of Mexico, however, daily normals are continually above 50° and hence that area, as well as a part of southwestern California, normally lacks autumn coolness (Map 6).

Winter commences, if daily normals below 32° indicate winter, in November in a con-

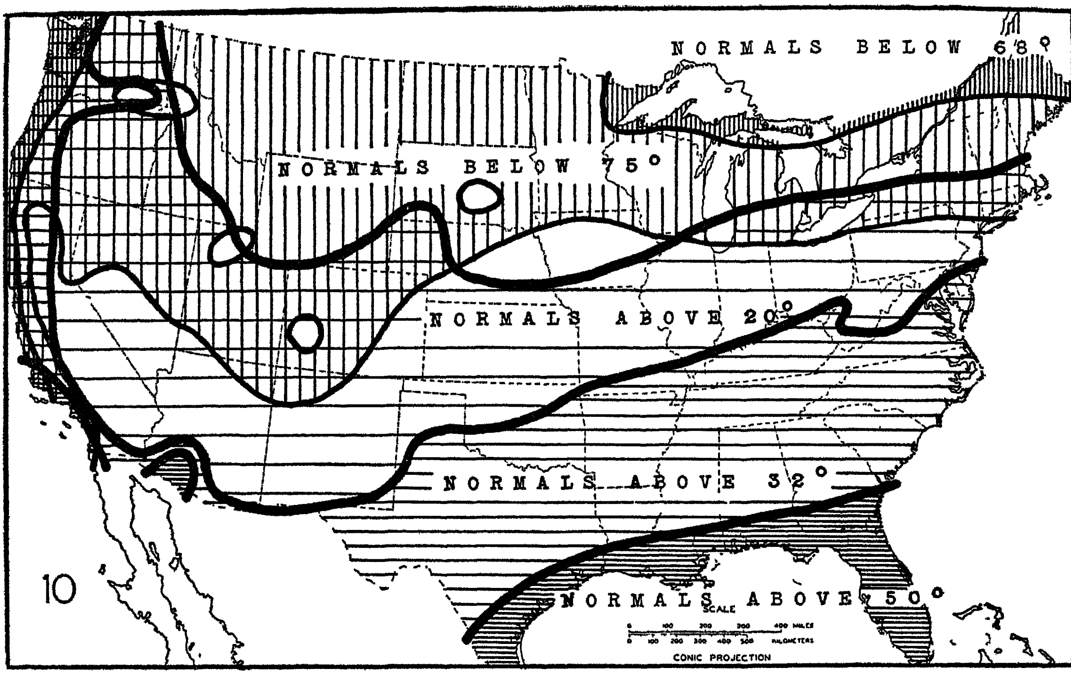


MAP 7. WINTER BEGINS (DATES WHEN DAILY NORMALS FALL BELOW 32° F.)

siderable northern zone, but not at all in a large southern region and also near the Pacific Ocean. Of course the South, even southern Florida, occasionally has freezing temperatures, but without winter as here defined (Map 7).



MAPS 8 AND 9. DATES ON WHICH COLD WINTER BEGINS AND ENDS
Above, MEAN TEMPERATURES OF DAY AND NIGHT FALL BELOW 20° F.; *below,* RISE ABOVE THIS TEMPERATURE.



MAP 10. SEASONAL ZONES BASED ON DAILY NORMAL TEMPERATURES

Maps 8 and 9 are placed together because both concern only the northern half of the country. Cold winter temperatures, here defined as daily normals of 20°, commence shortly before December 1 in the coldest part of the country and in December throughout a considerable northern zone (Map 8). They terminate, Map 9 shows, by February 1 in the southern margin of that belt, and during the first half of March in the northern section. The daily normals in the coldest part of that northern region descend to nearly zero for a few days.

The number of days of each year having daily normal temperatures of each of the types here considered may advantageously be briefly stated. Winter (normals below 32°) is lacking in about a third of the country, but in a large northern area it prevails more than a third of the year. Cool spring-fall (32°–50°) prevails for about four months (about two months in the spring and two in the fall) in a narrow, somewhat central zone, from which zone it decreases gradually northward and sharply southward. Such cool temperatures prevail for five or six months in much of Washington and Oregon and about five months in a belt from New Jersey to central Kentucky. Warm weather (50°–68°) prevails less than 100 days in a year in a large central area from which it increases in all directions. The Pacific Coast has the greatest number of such days, much of coastal California having more than 300 per year. New England has about 135 such days and the extreme Southeast and Gulf Coast and Florida have from 130 to 180. Summer (68° or higher) prevails more than half of the year near the Gulf but is lacking on the Pacific coast north of southern California and in three northern areas, the largest of which is in the Upper Great Lakes. Very hot weather (during which the normals—average of day and night—are 75° or higher) are lacking at the north and along the Pacific Coast, but prevail about a third of the year or longer in the Deep South. Cold winter (normals below 20°) occurs in about a fourth of the country, continuing for more than 100 days in an area extending from northeastern Montana almost to Lake Superior, and for more than 50 days in most of Wisconsin, South Dakota, and Wyoming.

Map 10 affords a sort of summary of the seasonal contrasts in the United States. The Deep South, with daily normals above 50°,

has no winter or cool spring-fall. It has summer (means above 68°) and hot summer (means above 75°). Most of the upper South lacks winter (means below 32°). A broad central zone has all seasonal types except cold winter. Much of the North lacks hot summer, and a small part of it lacks summer. Most of the Pacific Coast lacks both summer and winter. Various high western mountain ranges also lack summer, while some valleys have some hot summer.

The causes of the conspicuous seasonal contrasts in the United States are chiefly, of course, the latitudinal width of the country, its variation in elevation, and the effects of the ocean, the Great Lakes, and lesser surface features such as smaller lakes, slope, soil types, and vegetation. Significant also are the effects of precipitation. The regions which receive much snowfall warm up more slowly than the regions otherwise comparable which have little snow or winter rain.

The much greater effect of the Pacific Ocean than the Atlantic shown by these maps reflects the fact that the winds much more often blow from the west than from the east. The Great Lakes have a conspicuous effect especially evident in those maps showing exceptional warmth and cold. The Appalachian Mountains cause irregularities in the lines of all of the maps. The western high mountains have even greater effects although not shown by these maps. This is largely because the Weather Bureau records from the western mountain regions used in the construction of these maps come almost exclusively from cities in the lowlands, which have quite a different seasonal climate than that possessed by the near-by mountains, some of which are snow-capped.

Those readers who desire more details on the normal duration of various temperatures may consult my article in the *Annals of the Association of American Geographers* for June, 1943. Further explanation of the causes of the differences shown by the maps in the present article is presented in "Some Influences upon American Climate of the Ocean, Gulf, Great Lakes, Latitude and Mountains" in the *Bulletin of the American Meteorological Society* for March and May, 1943. "Novel American Climatic Maps and Their Implications," in the *Monthly Weather Review* of the U. S. Weather Bureau for June, 1943, will also interest some readers of the present article.

UNIFORMITARIANISM

Earth's forces fill the mind with awe:
Volcanic burst and earthquake shock,
The glaciers grinding tons of ice,
The hurricane and river's flood,
Mountain bared by avalanche,
And every great catastrophe.

Yet in the end far mightier
Are raindrop, snow, and rivulet,
With alternating sun and frost—
Faint forces, multiplied by Time.

That mountains only slowly rise,
And wear away to level plain
With only causes commonplace
As those that lie before our eyes,
This simple doctrine, understood,
Opens a vista to eternal time.

—Karl P. Schmidt

THE PASSING OF THE SALMON

By JOEL W. HEDGPETH

I will say from my personal experience that not only is every contrivance employed that human ingenuity can devise to destroy the salmon of our west coast rivers, but more surely destructive, more fatal than all is the slow but inexorable march of these destroying agencies of human progress, before which the salmon must surely disappear as did the buffalo of the plains and the Indian of California. The helpless salmon's life is gripped between these two forces—the murderous greed of the fisherman and the white man's advancing civilization—and what hope is there for the salmon in the end?—LIVINGSTON STONE. Address to the American Fisheries Society, 1892.

SEVENTY years ago the chinook salmon of California was an important natural resource, as famous throughout the world as the gold, the redwood trees, and the city of San Francisco. With a prodigal disregard for the future, hundreds of thousands of pounds of salmon were taken from the rivers and canned for shipment to all parts of the world. The present-day salmon fisheries of the Columbia River and Alaska were nonexistent in the seventies of the last century—then the entire industry was restricted to San Francisco Bay and the lower Sacramento River. Any other than "California Salmon" was unheard of in those days. But that fishery did not last long. In less than twenty years it reached its peak and began to decline as quickly as it had risen. The canneries moved on to the Columbia, to Seattle and Alaska, and the words Alaska and Columbia River on the labels of the new cans became so familiar that most Californians forgot about their own salmon.

The canneries alone were not responsible for the decline of the salmon. It is possible that the intensive fishery between 1864 and 1882 had less effect on the salmon runs than the hydraulic mining which damaged hundreds of miles of rivers during those same years. Later, when the salmon were no longer considered an important resource in California, dams without fish ladders barred them from many spawning areas or held the water back from the river beds below, and unscreened irrigation ditches carried young salmon out in the fields by the millions to die. Yet all this was not enough to destroy the salmon completely. For years they have been coming back, trying to repopulate what is left of their rivers. But within the last few years man has devised new dams and water projects which will cut off much of the remaining spawning mileage from the salmon.

The year 1872 is a significant one in the history of the Sacramento salmon. In that year the newly established United States Fish Commision received an appropriation of $15,000 to be spent in the "propagation of food fishes." At a meeting held by Commissioner Spencer Fullerton Baird and attended by various New England fish commissioners and members of the American Fish Culturists Association, Livingston Stone, a retired minister who had recently taken up trout culture, suggested the importation of California salmon to replace the vanishing salmon of the New England streams. It seemed a good idea at the time, for it was not known then that the Pacific and Atlantic salmon are entirely different fish, with radically different life cycles.

In the late summer of 1872 Livingston Stone and two young assistants found their way to the McCloud River (Fig. 1), nearing the end of their quest for spawning grounds of the chinook salmon. As they picked their way between the rocks and trees along the river bank they looked into the water for signs of salmon. Many strange and rough characters roamed the hills of northern California those days—miners, hunters, surveyors, and less respectable individuals, but these three New England gentlemen in search of a site for a fish hatchery were a new sort. Stone, the retired Unitarian clergyman who sought outdoor work for the benefit of his health, was a stocky man, conspicuously shorter than his two companions. His round head was framed by a pair of elegant brown dundrearies which partially concealed his large ears. One of his companions was a massive fellow whose solid chin was softened

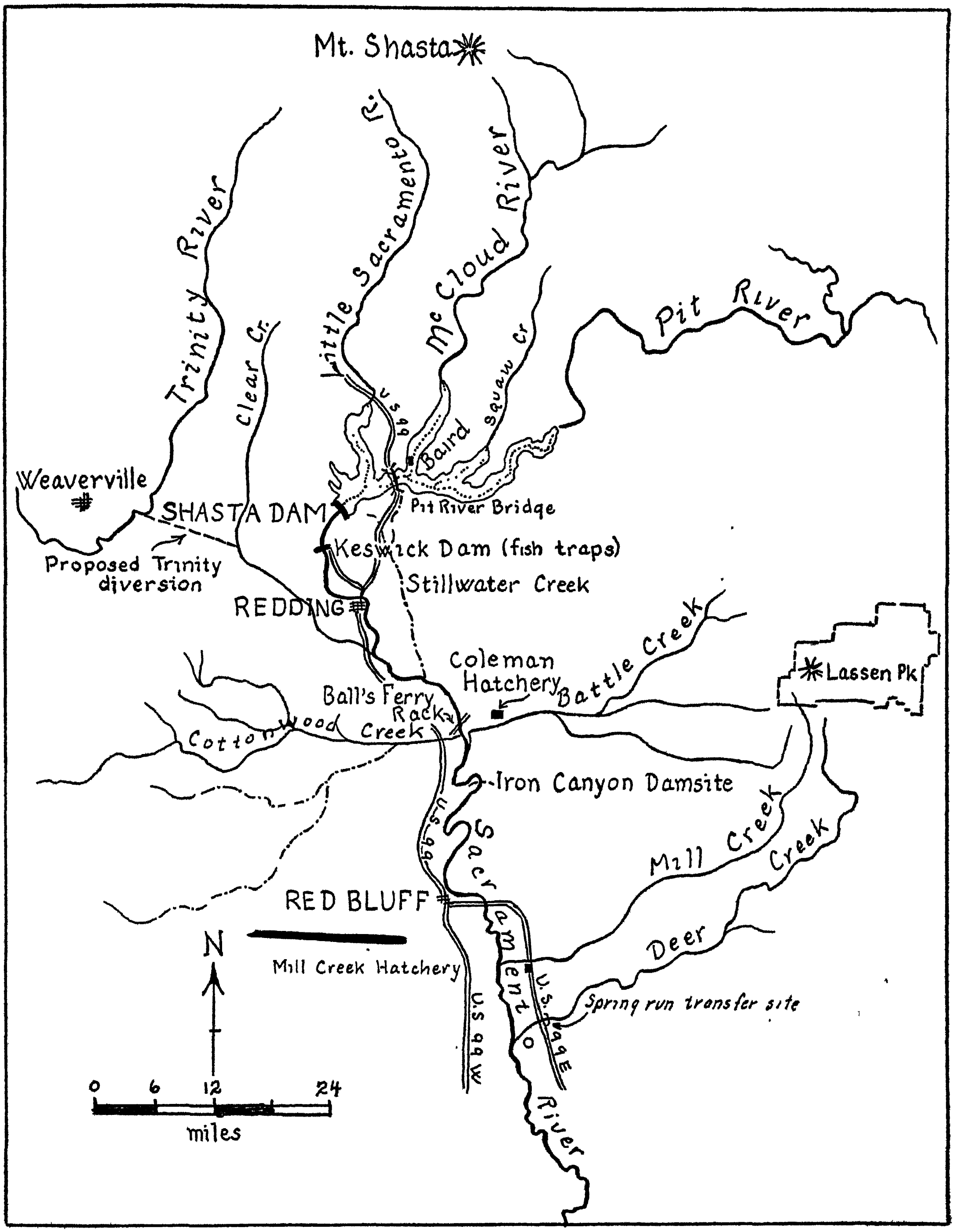


FIG. 1. THE UPPER SACRAMENTO RIVER AND ITS TRIBUTARIES

by a fringe of beard. The other was slighter, and beardless.

They did not have far to walk after leaving the ferry across Pit River just below the fork where the McCloud comes in, and they must have been unprepared for the scene ahead of them. Two miles upstream the McCloud turns toward the foot of a high

limestone crag, and then makes another turn to the left along the front of the crag. From the first turn the three men could see the gray rock towering above the dense forest, the smooth water at the farther bend, and the white churning of the water over the riffle at the nearer bend. To their left was a sandy beach and a low hill on which were clustered the brush huts of an Indian village. The Indians were fishing, wading out on the riffle with long double-pronged spears. On the other side of the river the forest grew almost to the water's edge. The retired parson named the crag Mount Persephone, but on the maps it now bears the prosaic name of Horse Mountain. The hatchery he built on the bank of the river within the morning shadow of the crag he named Baird in honor of the first Commissioner of Fisheries. Soon the new Shasta Dam will cover it under nearly three hundred feet of water.

The three men lost no time in getting down to work after arriving on this scene. They had hoped to hire the Indians to help them, but the Indians could speak no English. Working unaided in the hottest part of the summer, the fish culturists built a house, a flume for their water supply, and a series of hatchery troughs. The nearest sawmill was at the railroad terminus of Red Bluff, fifty miles to the south, and their lumber had to be hauled by wagon over the rough mountain roads. In spite of these difficulties the job was finished in two weeks, and on September 15 the first salmon were taken from the river. The hatchery became a famous place in northern California, as much for its cultured atmosphere—there were no oaths or card playing, and its superintendent became the acknowledged chess champion of the State—as for the queer things being done with salmon eggs.

Fish culture has not advanced very far beyond the practice of seventy years ago. Then a female was "stripped" of her eggs by squeezing her somewhat after the fashion of milking a cow. Today she is hit on the head with a club and the eggs cut out of her body, which is less wasteful of the eggs. After the eggs have been removed, a ripe male is forced to ejaculate milt over them. The fertilized eggs are then placed in baskets in long troughs of running water. For the first week or ten days they are picked over for dead eggs. After ten days the eggs become "tender" and cannot be handled. Even jarring the tray at this stage may kill all the eggs. Then, about fifteen or twenty days after fertilization, the eye of the embryo appears as a small black spot on the egg. In this eyed stage the embryo is very tough, and the eggs can be packed in trays with moss, burlap, or ice, and shipped to the far corners of the earth. They will hatch in six to nine weeks, depending on the temperature of the water in which they are placed.

The only important change in the above procedure has been the development of a drip incubator, in which the eggs are placed in shallow trays and water is percolated over them to cool them by evaporation. This method is not widely used, however.

The artificial propagation of salmon was so simple and obviously successful—after all, the fish were hatched—that it was assumed at the beginning that it was a notable improvement on the wasteful ways of nature. It is hard, in these sophisticated days, to realize the fascinated delight the early hatchery men took in their business of raising fish, how they watched over the eggs in the long troughs of cold water, picking them over with feathers like fussy hens, and the pride with which they watched the newly hatched alevins. They did not suspect that the natural hardihood and vitality of the eggs had as much to do with the success of their hatcheries as their human intervention in rescuing the eggs from the perils of the river.

That nature's methods of propagating salmon might not be as wasteful as they seem never occurred to them. Given half a chance, the salmon needs no assistance from man. It cannot, however, survive the total demolition of the rivers which is the inevitable result of power, mining, and irrigation developments.

During those early days of salmon culture in California no serious attempt was made to determine the efficiency of the natural spawning process. "In a state of nature, only two eggs in a thousand hatch," is the pontifical statement in one official bulletin. Livingston Stone dug into a nest and estimated that only "eight per cent" of the eggs

were fertilized. Although we still have much to learn about the life of the salmon, I suspect that natural spawning is at least as efficient as the hatchery method. Actual losses of eggs in hatcheries seem to range from five to forty per cent, with the emphasis in published records on the lesser figure. Nothing has been said of the possibility that hatchery reared fry may not be as healthy as naturally spawned fish. Certainly the practice of dumping large numbers of young salmon into a river was more hazardous to the fish than their natural method of emerging from the gravel, aside from any acquired differences in their constitution. In recent hatchery practice this danger to the young fish has been overcome somewhat by permitting them to escape from rearing ponds in a "natural" manner.

Livingston Stone and his contemporaries had no misgivings of this sort about the efficacy of fish hatcheries. While it should not be forgotten that the life cycle of the chinook salmon was not completely understood at the time, their assumption that the increasing fish catch was a demonstration of the value of the hatchery was a *post hoc* of the first magnitude. They did not consider that greater fishing effort can increase the catch in a declining fish population.

In the beginning the hatchery on the McCloud River was simply an egg-gathering station. During the first season 50,000 eggs were taken, of which 30,000 survived to the eyed stage. These were packed in sphagnum moss and shipped east. In March of the following year, 1873, a few hundred fingerlings were released in the Susquehanna River. Thus began the unsuccessful attempt to transplant the Pacific salmon to the Atlantic, which was not abandoned until ten or fifteen years ago.

We have learned a few things about the life of the chinook salmon since that day Livingston Stone and his two young assistants founded Baird hatchery. At that time no one knew when and where the salmon spawned, how often during its lifetime it spawned, or what happened to it after spawning. Although we are still trying to learn more about the wanderings of the salmon in the ocean, we have cleared up some of the points which mystified those pioneer fishculturists. Unfortunately we must still agree with David Starr Jordan, who wrote in 1896 that "writers of all degrees of incompetence, and writers with scanty material or with no material at all, have done their worst to confuse our knowledge of these salmon." Popular articles and newsreel shorts have perpetrated gross errors and even such an excellent book as Roderick Haig-Brown's *Return to the River* leaves important points open to misinterpretation by the lay reader.

There are five species of salmon of the genus *Oncorhynchus* (hooked nose) in the north Pacific Ocean. Two of these spawn in California rivers, but only one is found in the streams of the Central Valley. This is the chinook, quinnat, spring, or king salmon, referred to by ichthyologists under the formidable name of *Oncorhynchus tschawytscha.* The rainbow trout, a close relative of the Atlantic salmon, is also found in this drainage. The rainbow, a member of the true genus *Salmo* ("true" in the sense of being the first and best known genus of salmons), has races which leave the rivers and return as "steelhead" after a year or two of ocean life. The rainbow, or steelhead, unlike the Oncorhynchus salmon, can spawn several times.

The technical term applied to the salmon's habit of spawning in fresh water is anadromous. Some fish, notably the eels, are catadromous. They leave the rivers to spawn in mid-ocean. Whether the salmon is an ocean fish which spawns in fresh water or a river fish that has learned to go to the ocean for food and has not yet adapted itself to spawning in the ocean is apt to be an unprofitable argument, like the affair of the hen and the egg. The important thing to remember is that by spawning in fresh water, far from most of the hazards of life in the open sea, the salmon's relatively small number of eggs are given a much better chance for survival than if they had been released in the ocean to sink to the bottom in the presence of a horde of hungry gourmets. It is true that in a heavy run the reproduction may be less than when the run is moderate, because the salmon will dig up each other's nests. This frequently happens in Alaska, but the fact remains that natural reproduction did very

well until civilized man came upon the scene. It is strange that this did not occur to anyone in those days when it was still the fashion to inquire into the divine purposes of natural phenomena. Instead it was assumed that nature (and presumably, God) did *not* know best. No one thought of the life cycle of the salmon as an integrated phenomenon, in which the procedure of burying eggs in river gravel occupies much the same place in the salmon's life as the gray shark's method of hatching the eggs within its body, which insures maximum reproduction in spite of its limited fecundity.

The average life span of the chinook salmon is four years, but individual salmon may be six or seven years old before leaving the ocean, and a large percentage of some runs is composed of grilse. These are precocious fish of one, two, or three years stay in the ocean. Most grilse are males, but females are not uncommon.

Once it leaves the ocean and begins its migration up the river, the chinook salmon does not eat. It derives the energy for its difficult journey from the oil and fat stored up in its body during those years in the sea. The upstream migration is not always the continuous battle against powerful currents and waterfalls of popular fancy. In every stream there are eddies and backwaters, and the salmon makes use of these. Even when fighting rapids and climbing cataracts the salmon seeks out the places where the water can boost it against the main current of the stream. When at last it comes to a dam or sheer waterfall, it noses along the front of the falling water, seeking the center of the current. Then the salmon leaps, making a startling jump which is sometimes six feet clear of the surface of the pool. Such a leap may carry the fish cleanly over the crest, or it may send it into the solid green water at the brim. In either event, the salmon is over, for once it gets its broad tail into solid water it can go ahead. If the fall is more than a sheer six feet or the cascades are too long, even the largest salmon cannot pass and must fall back to spawn below the barrier, or fight the water until it dies, without fulfilling the mission of its life.

In the Sacramento River (Fig. 1) there are two principal runs: the spring run, which enters the river in March and April and passes Redding, just below the site of Shasta Dam, in May and June. One tagged fish made this journey of about 285 miles in 39 days; its average daily progress upstream was 7.3 miles. As the salmon of the spring run do not spawn until September and October, they must rest in cool deep parts of the river until they are sexually mature. The fall run leaves the ocean during the summer months and spawns in November and December. There also seems to be a small winter run which reaches the spawning beds in December and January.

When ready to spawn, the female salmon seeks out a riffle area at the lower end of a pool. Here, in gravel of medium size, from that of golf balls to apples, the fish digs a nest, or, as the English call it, a redd. The salmon accomplishes this by turning on her side and flapping her tail against the gravel. This creates a current on the bottom of the river which lifts the gravel. The current of the stream carries the gravel downstream until a fan-shaped pile of stones accumulates behind the pit. The hole thus dug is from six to eighteen inches deep. It usually reaches down to the finer gravel and sand beneath the coarse gravel of the river bed. Some observers believe that the salmon uses her tail and nose to dig into the gravel with a spading action, but I have not seen this myself. Only the female seems to dig the nest. The male hangs around, usually fighting off possible rivals.

After the nest is dug, spawning takes place. As the female discharges her eggs, the male swims alongside and releases his milt. Only a few hundred eggs are released at a time and are covered up after fertilization by the digging of another pocket upstream. In these pockets there is almost no current, and the eggs are seldom lost from the pockets in which they have been spawned while being buried. When all the eggs are spent, usually about 7,000 in the case of the salmon of the Sacramento (there may be as many as 10,000 or 12,000), the female, her tail and fins worn threadbare, guards her nest until the life ebbs out of her and her corpse drifts downstream. The male also dies.

When the eggs hatch, perhaps in sixty

days, the alevins, with their yolk sacs still clinging to their bellies, begin to wriggle out of the gravel in which they were born. During the first few weeks of their life, the young salmon live along the edges of the river, feeding on the insects that are abundant in the gravel-bottomed parts of the stream. Then the young fish begin to drift downstream toward the ocean. Some of them, having wintered over in the river, are about three inches long, others are barely large enough to shift for themselves. At this stage, when the fish are distinguished by marks like thumb prints along their sides, the young salmon are known as parr. They look very much like young trout. As they near the ocean, the parr begin to lose their markings and become young salmon.

Once in the ocean they grow rapidly, feeding on the nutritious crustaceans of the oceanic plankton. They wander in large schools up and down the coast, often hundreds of miles from the mouths of the rivers in which they were born. As the salmon grow, their scales also grow, and their growth is marked on the scales in rings like the yearly rings of the growing tree. By examining these scales, the approximate age of the fish can be estimated. Some have claimed that much more is written upon fish scales for him that knows the signs, but the salmon of the Sacramento River do not have scales as plainly marked as those of other regions.

It is usually taken for granted that the salmon returns to the stream in which it was born. It has not been proven to everyone's satisfaction, however, that all salmon return to the same stream in which they were born, or even that most of them do. Some outspoken dissenters to the theory that salmon find their way back to their native stream by instinct or "homing tendency" insist that the salmon respond to the carbon dioxide gradient of the water and that they might be enticed into suitable streams by tampering with the chemical balance of the water. Others suggest that the temperature of the water influences their selection of a stream. While neither of these schools of objectors has explained the embarrassing reluctance of all the salmon in a run to ascend the first stream that attracts the vanguard, something besides a mysterious subjective instinct or phenomenal memory, it seems apparent to anyone who has seen salmon runs, influences their selection of a stream.

There are, for example, the runs of two tributaries to the Sacramento: Mill and Battle Creeks (Fig. 1). Both of these streams have had hatcheries near their mouths for nearly fifty years, and for many years most of the salmon to enter these streams were intercepted and artificially spawned. The eggs were moved to Baird or to the state hatchery near the headwaters of the Sacramento River for hatching. Yet every year salmon continued to run into the two small streams in spite of this heavy drain on their spawning populations. Later, when the young fry were released into the same streams from which their parents had been taken, there was no significant change in the runs. In other words, there was no effect, favorable or adverse, on the salmon runs of Mill and Battle Creeks, as a result of human intervention. There are several possible explanations for this behavior. According to the home stream and natural spawning enthusiasts, enough spawning salmon escaped the fish-culturist's tender mercies to maintain a natural run. The numbers of salmon involved make this hard to believe. My own opinion is that the runs in these small streams are diversions from the main river run, attracted into the side streams by some quality of the water. It is significant that the salmon usually do not start to run in these streams until the fall rains have begun. No biologist is willing to admit that the homing instinct is hereditary, or acquired while the fish is still an egg, and such explanations are dismissed in passing, although there are stranger examples of instincts in the world of nature. The results of the only marking experiment conducted with Sacramento River fish would seem to support the explanation of diversion from a main run.

In this experiment, 15,400 fry hatched at Mt. Shasta from eggs gathered at Mill Creek were marked by clipping off two of their fins. None of these fish was recovered in the upper Sacramento River—which does not mean that none of the fish returned there, of course—but six adult salmon with mutilated fins were taken in Mill Creek and fifteen were caught at Battle Creek hatchery. If these

were the same fish, the experiment demonstrated that at least 21 of the 15,400 salmon returned to the same drainage basin in which they were released, and, further, that they apparently strayed from the main river, which was their adopted stream.

From time to time similar experiments have been made in other streams to test the home stream theory, usually by this method of marking young salmon and waiting for the return of the adult fish several years later. In none of these experiments has the number of returned fish been large enough to prove that most salmon return to their native stream. Such unregenerate critics as Dr. Henry Baldwin Ward steadfastly refuse to be convinced, and their position is best stated in Dr. Ward's words:

> No assumed mystical impulse makes them go back to a specific place because of their relation to that place at the start of their existence. They do, perhaps usually, return to the place because like their ancestors they react in a specific way to the stimuli they encounter on the journey. But they do this only so long as the conditions they meet on the journey remain unchanged. To characterize the situation as due to a parent stream theory is to adopt an empyrical [sic] conclusion with all the errors and limitations of empyrical findings. It is to abandon the search for a scientific basis and to lose the greater power over changing conditions which knowledge of controlling influences will give.

The genesis of the home stream theory has never been traced; it seems to have arisen as a spontaneous induction by analogy from similar phenomena in birds and bees. The strongest evidence in favor of a homing instinct is not experimental but anatomical or physiological. The average number of eggs in the Columbia and Sacramento river fish is different, and there also appear to be differences in such things as the number of gill rakers and pyloric caeca. While this indicates the existence of separate races in different river basins, it does not prove that salmon return to the identical tributaries in which they were spawned. If we do accept some sort of homing instinct as governing the salmon's journey for hundreds of miles in the open ocean from the mouth of the river in which it was born and back to the river, we have not settled the matter. Giving a phenomenon a name is no explanation. This discussion would be academic were it not for the various attempts to repair the damage being done to salmon streams by hydroelectric and irrigation projects by "training" salmon to spawn in new streams. These experiments place more trust in the homing instinct than is justified by the available evidence.

The most spectacular example of this experimentation with the lives of the salmon is the salvage program for the salmon of the Columbia River below the Grand Coulee Dam. The salmon are being intercepted at Rock Island Dam, 120 miles downstream from Grand Coulee. They are carried in special trucks to other streams which enter the Columbia between the two dams. Some of the fish are released to spawn in the rivers; others are handled at the Leavenworth hatchery and their fry released in the rivers. Since there is no way of determining which of these fish would have entered these streams of their own accord and which would have passed on to the upper Columbia, all the salmon that reach Rock Island Dam are taken. It is hoped that the salmon spawned or released in these rivers will return to the same streams and that it will not be necessary to intercept them at Rock Island Dam after the first complete cycle. If the fish do not justify this faith in their homing instinct it will be necessary to haul them from Rock Island Dam perpetually. The next year or two will answer the question, insofar as this part of the Columbia drainage is concerned. The first run, which returned last fall, is said to have behaved nicely. What is to happen on the Sacramento River is a different story—California is without such large streams as the Okanogon, Wenatchee, and Entiat Rivers in which to transfer its thousands of dispossessed salmon.

Although it will not be completed for several years, the Central Valley Project of California has reached the stage at which some of its major structures have become serious menaces to the existence of the salmon. As originally planned, this Federal project was to consist of two dams and a series of irrigation canals and pumping systems. The water stored at Shasta Dam on the upper Sacramento River will stabilize the flow of the river and generate power. A large part of this flow, according to the

original plan, was to have been taken up by pumps and shunted across the inverted delta area between the confluence of the Sacramento and San Joaquin Rivers. Then it was to be picked up by another pumping system and forced down to the middle San Joaquin Valley, to replenish the underground water of that region. Water was to be supplied to the upper San Joaquin Valley from Friant Reservoir on the San Joaquin River.

Of these three primary elements, Friant Dam is complete and Shasta almost so, but the Delta Cross Channel still remains in the blueprint stage. Instead of carrying out this last feature, it is now planned to construct two dams on the American River, about midway between Shasta and Friant Dams.

Although the Central Valley Project was commenced in 1936, with considerable fanfare and some rather gaudy publicity about "moving the rain," it was not until the summer of 1938 that any investigation of its possible effects on the salmon of the Central Valley drainage was begun. The first season's work of the investigation revealed an unexpectedly large run of salmon passing the site of Shasta Dam, and as later counts indicated, the run was on the increase. Apparently the Central Valley Project could not have been started at a more inopportune time as far as the salmon were concerned. While circumstances prevented an entirely complete count, the run seemed to be about 40,000 fish, all chinook salmon. This is about twice the number of chinook salmon being handled below Grand Coulee on the Columbia.

Every remaining stream in northern California was investigated in the hope of finding a place for these fish, but there is nothing left but a few streams hardly large enough to accommodate their own depleted runs. A fish ladder over such a dam as Shasta, which will be 560 feet high, is out of the question, nor would it be practical to trap all the salmon and transport them above the dam, because the ocean bound fry would have to be screened from the penstocks and river outlets by screen of not more than quarter-inch mesh, and they could not survive the fall over the spillway when the reservoir is full.

At first it seemed that it might be possible to rehabilitate one of the intermittent streams near Shasta Dam with water from above the reservoir, but this plan proved to be economically and biologically unsound, and was abandoned. At the outset it was realized that there would be more salmon than any program of stream rehabilitation or transfer could handle, and that it would be necessary to construct a hatchery if a serious attempt to save the salmon was to be made. There were very few suitable hatchery sites in the Valley, and almost no place to hold a large number of spring run salmon, which have to be kept in cold water (60° F. or less) during the hottest part of the summer in order to survive until ripe for spawning. Only Battle Creek (Fig. 1), of the streams within fifty miles of Shasta Dam, might be used for this purpose. The history of the existing Battle Creek hatchery offered little encouragement for further hatchery development, but as the best had to be made of a bad bargain, a new and larger hatchery has been built. As many salmon as possible are to be carried by trucks to Deer Creek, which enters the Sacramento about sixty miles below Shasta Dam, but the number of fish which this stream can hold is very small.

For most of the run, there was nothing left but the river itself. Accordingly, a series of racks has been installed, and the salmon are being held in the river between Keswick Afterbay Dam near Redding and the mouth of Battle Creek. Although it will require several years to determine experimentally whether the salmon can be trained to spawn between these racks instead of in the headwaters where their ancestors did, a large number of salmon have spawned in the areas, and those concerned in the administration of the experiment have been cautiously optimistic in their public declarations. Unfortunately, there are indications that this experiment may not be given a chance to prove itself. Within the last few months the U. S. Engineers have announced plans to dam the Sacramento at Table Mountain near Red Bluff as a flood control measure. This dam would undoubtedly be too high for fish ladders, and in spite of the artful references to a "low level" structure, it will back up water far enough to flood out the new hatchery. Official recognition of this conflict in agency plans has not been realistic, and the Engi-

neers have given no intention of being willing to defer their project for several years until the Bureau of Reclamation salvage project is given a chance. Until this issue is settled, the salvage project can only be considered an expensive laboratory experiment. But the Bureau of Reclamation itself appears to be more concerned about the possible conflict in power production than the danger to its salmon project. When storage of water was begun at Shasta Dam in the winter of 1943–44, public action was necessary to prevent the Bureau from cutting down the river flow to such an extent that large areas of spawning beds would have been left dry, in the very parts of the river it had spent half a million dollars to develop for the benefit of the salmon.

The salmon population of the lower Central Valley in the tributaries of the San Joaquin River is even larger than the run in the upper Sacramento. During the year 1940, for example, more than 170,000 salmon were counted into such rivers as the Tuolumne, Merced, and upper San Joaquin. The salmon's lot may be happier in these streams than in the Sacramento. There are fine gravel areas in these rivers below the dams that have been built or are being planned. The original plan of the Central Valley Project to dry up the San Joaquin, without any concern for the appearance of the river or the needs of the fish, will have to be altered to allow living room for these fish. Recent observations of the behavior of salmon blocked by Friant Dam indicate that the spring run fish, at least, will fall back downstream to spawn, and the recognition that fish may have some water rights may undo some of the damage that has been done in these streams over the years.

Unfortunately, there seems to be no end of engineering plans in sight. It might be possible to arrive at some adjustment between salmon and engineering if the latter were stabilized. Whatever the reasons behind the apparent abandonment of the Delta Cross Channel, the engineers in charge of the project assure us that this element of the plan has not been abandoned but only deferred. If constructed, the Delta Cross Channel and its pumping plants would present formidable difficulties to any salmon salvage or conservation program because of its huge pumps and diversion barriers. Nor is this all. There is a plan ultimately to cut off the entire river system by a salt water barrier at the upper end of San Francisco Bay. This barrier, if constructed, would cut off all other fish, such as striped bass and sturgeon, which pass from salt to fresh water, as well as the salmon. As for the Columbia, the construction of dams has barely started. A dozen more are to be built as soon as the war is over.

In spite of the fact that most of these projects are already in the blueprint stage, we are still assured that every effort will be made to save the salmon. Indeed, the official press release from the Bureau of Reclamation, on the occasion of the initial generation of power at Shasta Dam, states that release of water from the dam will "protect the salmon and other fish and wildlife interests." But there can be such a thing as too many dams, and it would be more honest if the agencies concerned were to admit frankly that the passing of the salmon is an inevitable result of their projects, instead of issuing such misleading press releases. If this possibility had been admitted before the start of the projects, it is possible that they would not have been so enthusiastically received, for no matter how insignificant the intrinsic value of a salmon run may appear to be when set against the dazzling prospectus of millions of dollars worth of dams, the fact remains that a salmon run is, if properly respected, a perpetual natural resource.

It may already be too late, as far as the Sacramento, and perhaps the Columbia, is concerned, to recognize that a river has certain natural functions which should be respected above its use as sites for public works projects, but there are other rivers, especially in Alaska, where the water rights of fish should be respected even more than the artificial rights which man recognizes in his law courts. For, as Harold Child Bryant wrote in 1929:

> There are certain natural resources which are far more valuable than any handiwork of man. When people are hoodwinked into believing that the brains of man can build artificial structures more useful to civilization than raw materials represented by natural resources, danger is ahead. Works of man may be built and destroyed at will, but there is yet to be found a man who can create a natural resource, such as is represented in fish life.

THE PROBLEM OF ORGANIC FORM*

IV. CHEMICAL EQUILIBRIUM AND ORGANIC INTEGRATION

By S. J. HOLMES

Life is the expression of a dynamic equilibrium which obtains in a polyphasic system.—F. G. HOPKINS.

IN our endeavors to penetrate into the mysteries of life we are often led to fix our attention on those characteristics of nonliving bodies which find parallels in the activities of living organisms. The hope of throwing some light on fundamental life phenomena has afforded a potent spur to researches on the form, molecular arrangement, and regeneration of crystals; the chemical nature and synthetic and destructive action of enzymes; the properties of semipermeable membranes; the behavior and structural make-up of colloids, and many other phenomena of biophysics and biochemistry. These researches are being carried on by an army of technically trained investigators who are turning out an imposing and rapidly swelling flood of literature, most of which would be unintelligible to the typical biologist of the Victorian era. Turn over the pages of *Biodynamica, Growth,* the *Journal of General Physiology, Bios,* or *Protoplasma* and one encounters a large proportion of papers which cannot be adequately understood without more knowledge of mathematics, physics, or chemistry than is possessed by most biologists of the traditional sort. The task ahead of this modern army is colossal. Its soldiers are inching along over a wide front, sometimes by-passing and closing in on positions which have long proved impregnable to a frontal attack. Not improbably we shall see the fall of some old strongholds in the not distant future.

The efforts of the biological speculator in contributing to the successful assault on fundamental positions, while often of doubtful value and sometimes even meriting the reproach of being only an obstacle to progress, are, of course, essential for advance, and they frequently perform a valuable service even if misguided. If one looks back over the history of theories of development and regeneration, it will be seen that a number of speculations that have proved to be wrong have led to experimental researches which have yielded valuable new insights. In the development of theories of morphogenesis there is a tendency to get away from artificial constructions like the physiological units of Spencer, the plastidules of Haeckel, and the gemmaires of Haacke, and to interpret the phenomena in terms of known processes, whether physical, chemical, or physiological. But the basic defects of so many of the modern, as well as the older, speculations on morphogenesis is that they are not theories of balancing. The field theories and the doctrine of gradients, and those based on so-called "crystal analogies," whatever elements of truth they contain, all suffer from their inability to give a plausible account of the coadaptations which play an indispensable role in formative processes.

In the view which I have developed in the preceding papers, morphogenesis is largely a result of physiological balancing. The term balancing implies a tendency to settle into a state either of immobility or of action which runs along in a fairly even course. Organisms possess many mechanisms by which their functions are checked when in excess and speeded up when they lag below a certain norm. In this way a balance is maintained which tends to keep things running *in statu quo.* If we seek an analogue of this kind of behavior in the nonliving world, we may find it in the tendency to equilibrium exhibited in ordinary chemical reactions. When one adds acetic acid to alcohol, to use a well-worn illustration, there is obtained a certain amount of ethyl acetate and water. The reaction stops short of transforming all of the alcohol, leaving a definite proportion of alcohol, acetic acid, ethyl acetate, and water, which depends upon the relative masses of the ingredients employed and also upon temperature and other external factors. Should any one of the ingredients be removed, more of that substance would be

* Continued from p. 260 of the preceding issue.

produced until a new equilibrium is reached. Regeneration of the missing substance is, as a rule, direct and it comes to an end when a new balance occurs.

What is the relation of chemical balancing to the balancing which occurs in the physiological activities of the organism? And is it also possible to construe in terms of chemical equilibration the regulatory form changes that take place in development and regeneration?

That the functional and formative activities of living organisms regulate themselves in ways that are fundamentally akin to those involved in ordinary chemical transformations may be regarded by many as a grandiose generalization based on a slender and far-fetched analogy. Whatever be the merits or demerits of the idea, it may be worth while to explore its possibilities somewhat, and perhaps all the more so because it presents a viewpoint that has attracted little attention on the part of most writers on the problem of organic form.

Were one to state that all biological processes are physical and chemical in the last analysis, and that the principles of mass action and chemical equilibrium apply to them as much as in the inorganic world, many biologists would assent at once. But a bare formulation of this kind would not be very helpful unless one can make its application more clear in relation to specific problems. The role of chemical equilibration in the integration of bodily functions is dwelt upon extensively in the literature on physiology. I need not discuss the part played by mass action in the chemical changes occurring in respiration and in the maintenance of the normal pH of the blood. In many other ways functional balancing seems to be chemical balancing plus certain accessory responses on the biological level.

One may well imagine that chemical equilibrium may be a dominant factor in many cases of functional hypertrophy. In a possibly overambitious paper on "The Problem of Form Regulation," published in 1904, in which stress was laid on the possible connection between form regulation and chemical regulation, I ventured to suggest:

> If the checking of the growth and functioning of an organ when its products reach a certain degree of concentration is due to the fact that a chemical equilibrium is reached which prevents more of those substances from forming, the self-regulation of functions which goes on in an organism may to a great extent be the outcome of the tendency toward chemical equilibria. . . . if a particular substance is gotten rid of with more than the usual readiness we should expect that substance to be produced in increased amount.

This, in many cases at least, would probably lead to an increased development of the organ or part concerned. I would not assert that all cases of functional hypertrophy can be interpreted in so simple a manner, but the case may serve to illustrate a possible way in which a widespread mode of physiological, and hence of form, regulation may be brought into relation with the principles of chemical equilibration.

An important role in balancing activities is played by the inhibitory effect of an organ's own products. A yeast cell in a sugar solution continues to split up the sugar to form alcohol and carbon dioxide until the percentage of alcohol reaches a point at which it checks its own further production. This cessation is not due to a reduction of the food supply. It can be brought about at any time by the addition of alcohol to the medium. The precise steps by which alcohol results in checking the enzyme activity of the yeast cell we do not know, but it is not unreasonable to look upon the whole process as one of chemical equilibration. If we were to add some substance which would combine with the alcohol in a way that would render it innocuous, the yeast cell would doubtless respond by producing more alcohol. Suppose now that this substance were produced by some other organism occurring in the same solution. If not injurious to the yeast plant in other ways, the organism would tend to enhance the enzyme activities of the yeast cell and probably lead to its growth and multiplication. If the alcohol contributed as food or otherwise to the vital activities of the second organism, we would have a sort of symbiotic relationship which would tend after a time to settle automatically into some kind of a balanced state. Up to a certain point each organism would tend to evoke the functional hypertrophy of the other. We have assumed that similar relationships are widespread among the various parts of a

living organism and that they automatically lead to functional adjustments which play an important part in building the organism as well as in maintaining its life.

The general failure to accord adequate recognition to the role of chemical equilibration in formative processes is doubtless due in part to certain evident differences between chemical balancing and the processes of morphogenesis. Two outstanding differences are (1) the tendency of chemical equilibration to result in homogeneity throughout the mass, or a relatively small degree of diversity where a gas or a precipitate is formed, and (2) the tendency of chemical processes to settle down into a state of apparent rest in which, under constant conditions, energy changes between the mass and the environment do not occur; whereas in an organism they continue to increase in complexity and amount over a considerable part of the life cycle. The first of these topics has been discussed briefly in Part III, "The Problem of Divergent Differentiation," in which it was pointed out that increasing differentiation is made possible under the peculiar conditions in which chemical reactions take place in the colloidal structures of living substance. The conditions differ from those in a glass container because the organic container actively participates in the reactions that occur and is itself built up and torn down and remodeled by these processes. It is provided with many kinds of enzymes and enzyme precursors which are affected differently in different regions and which produce compounds which, instead of diffusing uniformly, are in part anchored *in situ* and build up new complex colloidal configurations. Enzyme action is often greatly accelerated through adsorption on the colloidal structures of protoplasm, as is shown, for instance, in the ingenious experiments of Warburg on respiration. The action of these enzymes, which goes on most rapidly when adsorbed on colloids, naturally varies with the structural character of a living substance and the extent of its exposed surfaces. The adsorption of various colloids on the surface of micelles produces variations in the ways in which the micelles join together to build up crystalline aggregates. These and other factors may affect the local variations in the formation of fibrils, colloidal networks, and other configurations arising in histogenic differentiation.

The basis for the structural complexity exhibited by higher organisms is in large part the possession of a varied assortment of genes which, by the constructive enzyme actions they inaugurate, give rise to different products, some of which diffuse out and serve as evocatory agents that arouse different kinds of genes in other areas. Under the conditions indicated, chemical equilibration, instead of leading to homogeneity, may actually give rise to regional diversity as a result of the evocatory effects of gene action. Genes can only exert enzyme activity when the proper substances are available. These may be furnished by the action of other genes. At different times genes which have hitherto served only by standing and waiting are aroused from their lethargy and begin to play an active part in the production of further changes. As more substances are produced, more genes are called into service until a degree of complexity is reached which is determined by the original gene complex and its cytoplasmic investment. These genes in their setting furnish the original cast with which the drama of development begins. They enter upon the stage at stated periods as the plot unfolds. At times, since the drama does not always run smoothly, they may appear to exercise considerable ingenuity in improvisation. But, as we have before contended, their behavior is really very stereotyped, and their seeming originality is provided for in advance by the playwright.

The dynamic equilibrium occurring in an organism is sometimes designated as a "pseudoequilibrium," and contrasted with that occurring in chemical reactions because it involves continuous imbalance and changes of energy. Life, it is said, is possible only because equilibrium is never attained. Something always happens to upset the balance. In this respect an organism is like a candle flame, with which it is often compared. The flame is in a state of dynamic equilibrium and maintains a constancy of form despite outer changes by which it is modified. Forces that make for static equilibrium are ever operating, and if the flame were enclosed in a container cutting it off from

everything else, it would quickly resolve itself into an inert mixture of gases. It is normally prevented from so doing by a continued intake of energy contained in the melted tallow or wax. This supply of energy converts it into a dynamic system ever striving toward a static condition. The final result of burning is a lot of compounds in which potential energy differences are leveled down. In an organism the situation is much the same. Among plants a rather exceptional procedure occurs in the ability to employ the light of the sun to build up energy-yielding carbohydrates. Plants are comparable to candle flames that make their own tallow by absorbing free energy from their environment. The plant, if it can be called a plant, that first accomplished the Promethean theft of fire from heaven and made its energy available took a step of incalculable importance in the evolution of life. An imposing monument should be erected in its honor.

After all, the distinction between static and dynamic equilibria need not disturb us. Fundamentally it is food, or sunlight which is used in the synthesis of food, that continually unsettles the organic balance and furnishes the energy for running the living machinery. A part of this energy is used in the endothermic reactions involved in forming complex organic compounds. Its disposal and direction in building is largely determined by genes, which we must be careful not to look upon as little deities but as centers of activity quite strictly under the control of the essentially democratic system.

Amid all the diversities that result from the process of development, the original cast of genes is retained and forms the basis of the power of reproduction and the restoration of lost parts. The material basis for all the chemicals required for morphogenesis resides in every part and constitutes the potency of working out new equilibrations.

Sometimes dedifferentiation forms an essential part of the remodeling of organic structures in preparation for new construction. An essential condition for reconstruction is afforded by the labile state of living matter, which is often in a transitional state between a sol and a gel. Regional differentiation is associated with different types of gelation, and it does not tend to become swamped out through chemical equilibration because of its semisolid consistency. Under altered chemical conditions many fixed compounds may undergo solution, and then equilibration would tend to undo the work of producing structural diversity, and the system would be brought back to a state in which it can make a new start. Changes of phase play a role of enormous importance in form regulation. Gelation and solution are the favorite procedures employed by the architect and remodeler of the living body. The formation of a more or less solid framework permits the organism to accumulate structural diversity and hence to run through with a sequence of changes. These semisolidifications give the diversities that arise through interaction the degree of permanence required in building and also the degree of modifiability required in regulatory adjustments.

In the early stages of development and in lower organisms the formative reactions are elicited mainly by contiguous parts. Experiments have supplied many instances of such influences, although efforts to determine the substances producing the evocatory effects have thus far yielded only a modest return. In a complex organism containing many specific chemical factories in different regions the part played by chemical products as formative agents is more conspicuous, as is illustrated by the functioning of the endocrine glands. Under such conditions chemical equilibration involves a system of exchanges in which the *milieu interne*, the great stabilizer, constitutes an essential medium. Organ A contributes its products to this medium and therefore affects organ B (to say nothing of others), which responds by changing the medium in ways that modify the functioning of A. Balancing comes to be a many-sided process involving all the chemical factories of the organism, and it is often brought about in very roundabout ways and may even enlist the services of gross physical changes.

Whatever relationships exist between chemical equilibration and physiological and morphogenic integration are greatly obscured by the complexities of the latter phenomena. These complexities have grown up

in large part through what may be termed a successive accumulation of intercalations. The primitive relationship between A and N, instead of being direct, comes to be mediated by other activities D, E, F, etc., which have their specific structures relating to their specific activities. The hunger of a yeast cell may be satisfied by increased absorption of food owing to a deficiency in its protoplasm. A similar lack in the protoplasm of a lion is compensated in a very indirect way involving search for food, efforts to overcome and devour prey, the operations of mastication, swallowing, digestion, and others which enlist the activities of nervous reflexes, the secretion of digestive glands, and the co-ordinating functions of several hormones. In a paper on "How Life Becomes Complex" I have pointed out that in the course of evolution the basic functions have become associated with secondary activities which are subservient to their performance and that these in turn became associated with other activities which conduce to their performance, so that function B, which is subservient to A, is followed by the development of C subservient to B, D to C, and so on until a long chain of diverse activities very different in kind and in their associated structures is finally formed. Thus, the spinning of an orb web by the spider is the last event in the evolution of a chain of superadded, accessory activities that conduce to the primitive function of assimilation. This accumulation of acts and structures accessory to others which are accessory to still others makes functional relations very involved and the processes of physiological integration correspondingly complicated. The equilibration of basic functions comes to involve the regulation of many other subsidiary activities by which they are carried out. The maintenance of a fairly constant pH in our blood, for instance, is accomplished by means of secondary procedures, such as the functioning of the kidneys, the reflex activities of the respiratory center set up by carbon dioxide in the blood, and other reactions enlisting the services of various organs of the body. Basically the process may be considered as one of direct chemical equilibration, as in one sense it continues to be, but it has come to enlist the aid of accessory activities to such an extent that one might almost view the whole of life as centering around it.

In a relatively simple organism, such as an unfertilized egg cell, one may reasonably look upon most of its regulatory powers as springing from the equilibrating action of physical and chemical processes. After the removal of a part, the cell would round up, and the altered proportions of the various stuffs in the cytoplasm would be brought back to a normal distribution through chemical equilibration. The cell has a physiology of its own, which involves the basic functions that are carried out in the adult by very elaborate mechanisms. When one tries to imagine how these two physiologies are connected by intermediate stages, as they must be, he becomes lost in a speculative maze. Each stage tends to regenerate its own lost parts and to regulate its own functional balance. But these adjustments result only in a restoration of a passing phase. We might conjecture that each stage tends to pass on to the next for essentially the same reason that it tends to restore itself. Each step made in meeting one condition may incidentally involve a further imbalance which, by awakening a hitherto dormant gene, may participate in effecting a new approximate balance. So life becomes a ceaseless striving for a peaceful heterogeneous equilibrium, the attainment of which would result only in death.

MAN'S MOST CREATIVE YEARS

QUALITY VERSUS QUANTITY OF OUTPUT

By HARVEY C. LEHMAN

In previously published studies[1] it has been found, for numerous kinds of creative endeavor, that a brief age interval exists during which men are most likely to be maximally efficient. Both prior to and subsequent to the optimal age level of greatest efficiency, men tend to do somewhat less than their very best work. The present study sets forth the relationship between quality of output and quantity of output.

How can we make a quantitative comparison of quality and quantity of scholarly and artistic work with respect to the ages of those who produced them? In a given field of endeavor we must take a good sample of the works that are regarded by authorities as outstanding, and we must know the name of the author of each work and his age when he produced it. These superior works we shall regard as representing "quality." Then for comparison we must take a larger sample of similar works (by the same or by different authors) which for one reason or another must be regarded as of lesser merit than those of the first sample. These more numerous, run-of-the-mine works we shall regard as representing "quantity." Having acquired such data, our problem is simply to make a fair comparison of rate of production of outstanding works and of less significant works at several age levels, or age classes, throughout the productive years of man's life. Such comparisons are always made by means of graphs. The simplest representation of the data would show the number of works produced at each age level in the form of a frequency distribution. But two such curves would not yield a fair comparison of our data for two reasons: first, our samples are not of the same size; second, the number of younger workers exceeds the number of older workers and consequently the output of the former group would be expected to exceed that of the latter. We need a method of comparison that will eliminate absolute numbers and put production on a percentage basis. Therefore, instead of plotting numbers of works against corresponding age levels, we shall plot the average annual production per individual in each chosen age level of 5, 7.5, or 10 years. Furthermore, we shall express the average annual production per person in each age level as a percentage of the highest production, which we shall call 100 per cent. Thus every curve in the graphs of this article has a peak at 100 per cent. In all graphs the solid line represents age distribution of rate of production of outstanding works; the broken (dot and dash) line, works of lesser merit; and in two graphs a dotted, or dash, line, works of still lesser value. In the manner described comparisons were made of quality versus quantity of output in eleven different fields of endeavor. The results are illustrated and discussed in the paragraphs that follow.

Geology. The solid line in Figure 1 presents the chronological ages at which 65 individuals, now deceased, made 99 notable contributions to the science of geology. The data employed were obtained from *A Source Book in Geology*[2] by Mather and Mason, who give extracts from contributions that they regard as the most important. This line reveals clearly and unmistakably that, in proportion to their number, men have made notable contributions in geology most frequently during their thirties.

What is found when an analogous age-curve is constructed for geological contributions of somewhat lesser average merit than those listed by Mather and Mason? The broken line of Figure 1 presents age data for 5,386 geological contributions[3] by 169 geologists, now deceased, the average number of contributions per individual contributor being 31.86. It seems obvious that these 5,386 contributions are of *lesser average merit* than are the 99 contributions listed by Mather and Mason. If this assumption be valid, the broken line may be said to reveal quantity of geological output at successive age levels. It attains its apogee at ages 70

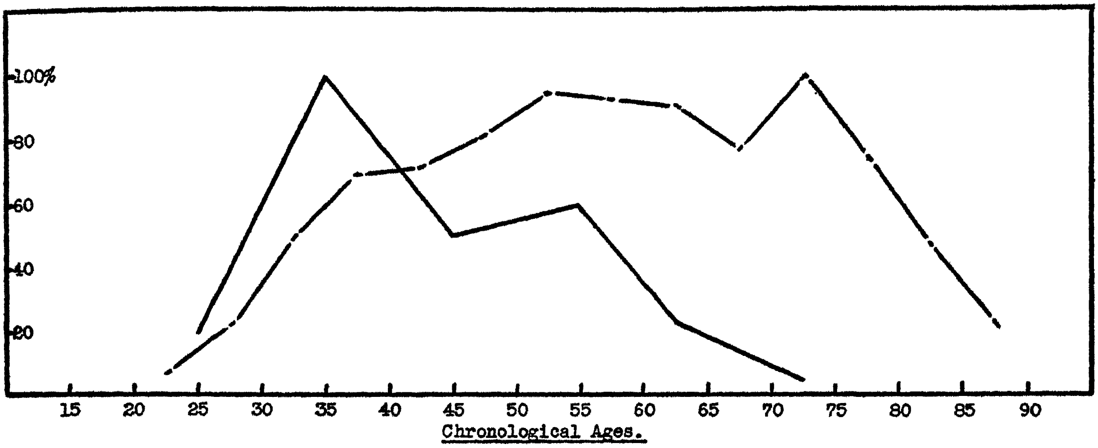


FIG. 1. AGE VERSUS PRODUCTION IN GEOLOGY
Solid line, 99 SUPERIOR CONTRIBUTIONS BY 65 GEOLOGISTS WHO WERE BORN BETWEEN 1801 AND 1857. *Broken line,* 5,386 CONTRIBUTIONS OF LESSER MERIT BY 169 GEOLOGISTS BORN BETWEEN 1800 AND 1833.

to 74 and sustains itself rather well over a wide age range. In contrast, the solid line rises more rapidly to a peak at 30–39, and it also falls off at a more rapid rate.

A curve that pictures a large number of works per contributor tends to remain high at most age levels because it requires many years of effort for a group of men to produce an average of 31.86 geological works. But why does the peak of production for the more carefully selected contributions occur so much earlier than does the peak for quantity of output?

Psychology. In Figure 2 the solid line presents the ages at which 50 psychologists, now deceased, made 85 important contributions to their science, the average being 1.70 contributions per contributor.[4] The broken line sets forth similar information regarding 4,687 contributions by 339 contemporary psychologists.[5] The solid line is highest at ages 35 to 39, inclusive, whereas the broken line, representing contributions of lesser average merit, attains its peak five years later, namely, at ages 40 to 44, inclusive.

Some readers may wonder whether the differences in the shapes of the curves (Figs. 1 and 2) which set forth quality versus quantity of output may not be due, in part at least, to the fact that different groups of workers produced the contributions called "supe-

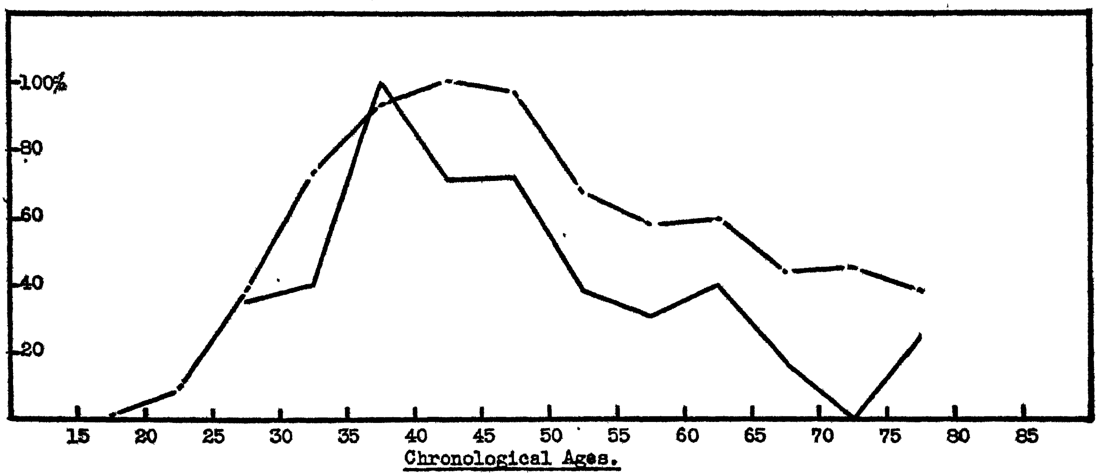


FIG. 2. AGE VERSUS PRODUCTION IN PSYCHOLOGY
Solid line, 85 SUPERIOR CONTRIBUTIONS BY 50 MEN, NOW DECEASED, AVERAGING 1.70 PER CONTRIBUTOR. *Broken line,* 4,687 OF LESSER MERIT BY 339 CONTEMPORARY PSYCHOLOGISTS, AVERAGING 13.82 PER MAN.

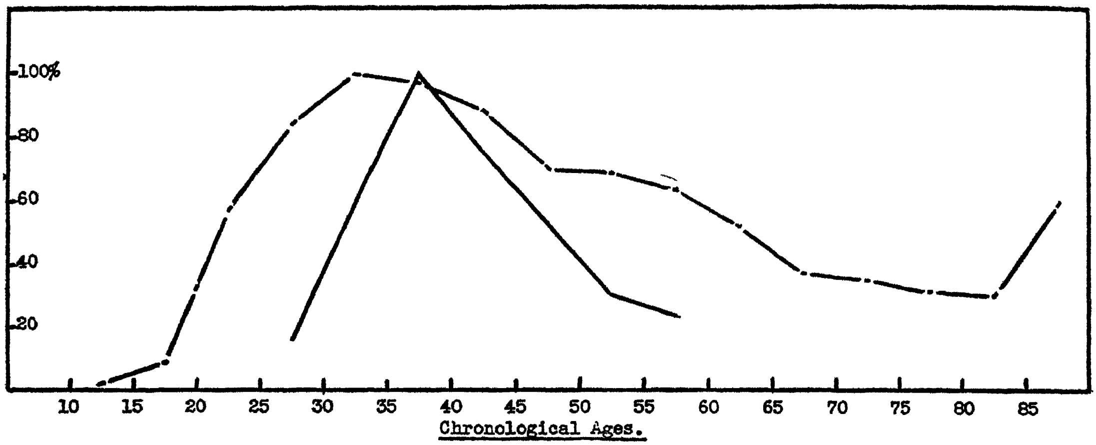


FIG. 3. AGE VERSUS PRODUCTION OF GRAND OPERAS
Solid line, THE ONE BEST-LOVED GRAND OPERA BY EACH OF 51 COMPOSERS WHO ARE NO LONGER LIVING. *Broken line,* 532 GRAND OPERAS BY THE SAME 51 COMPOSERS, INCLUDING OPERAS NOT OFTEN PERFORMED.

rior" and those labelled "of lesser merit," respectively. The data in the following examples indicate that the foregoing hypothesis is of doubtful validity.

Grand Opera. In Figure 3 the solid line sets forth the chronological ages at which each of 51 composers, now deceased, produced his one best-loved grand opera; the broken line presents the ages at which *these same 51 men* produced a total of 532 grand operas.[6]

A word of explanation as to how the best-loved grand operas were identified may be in order at this point. With NYA student assistance, which was essential for the completion of this study, the present writer made a composite study of 15 different books each of which was alleged by its author to contain a select list of those operas that possess lasting merit and that opera-goers are most likely to hear. Analysis of the 15 books was made on the assumption that an opera listed in many different books, which contain so-called "favorite" operas, is likely to be more popular than is another opera by the same composer which is listed in only a few such books. In the construction of the solid line of Figure 3 no opera was used unless it appeared more frequently than any other opera produced by the same composer.

It will be noted that the solid line attains its peak at ages 35 to 39, inclusive, whereas the broken line attains its peak five years earlier. The earlier rise of the curve for quantity of output suggests that the grand opera composer must have a practice period prior to the accomplishment of his best work.

Short Stories. In Figure 4 the solid line presents the ages at which 87 best-liked short stories were either written or first published by 38 authors, now deceased. The stories selected were those that appeared most often in 102 books of favorite short stories. No story was included unless it appeared in 4 or more of the 102 source books.

The broken line presents the chronological ages at which 416 other short stories were produced by the *same 38 authors* who wrote the 87 best-liked ones. Age data were obtained from Jessup.[7]

Although the peaks of both curves are rather narrow, the peak of the solid line is more pointed than that of the broken line. It should be realized that the abrupt drop of the former curve does not signify that either individual or group proficiency declines at the same rapid rate. The solid line was so constructed as to reveal merely the number of peak performances which were attained at successive chronological age levels. Hence, a number of short stories only very slightly inferior to some of those used in the construction of this line have received no credit at all. If fractional credit were awarded for these just noticeably inferior short stories, the solid line would rise and fall more gradually. Its sudden rise and abrupt descent indicate, therefore, merely a consid-

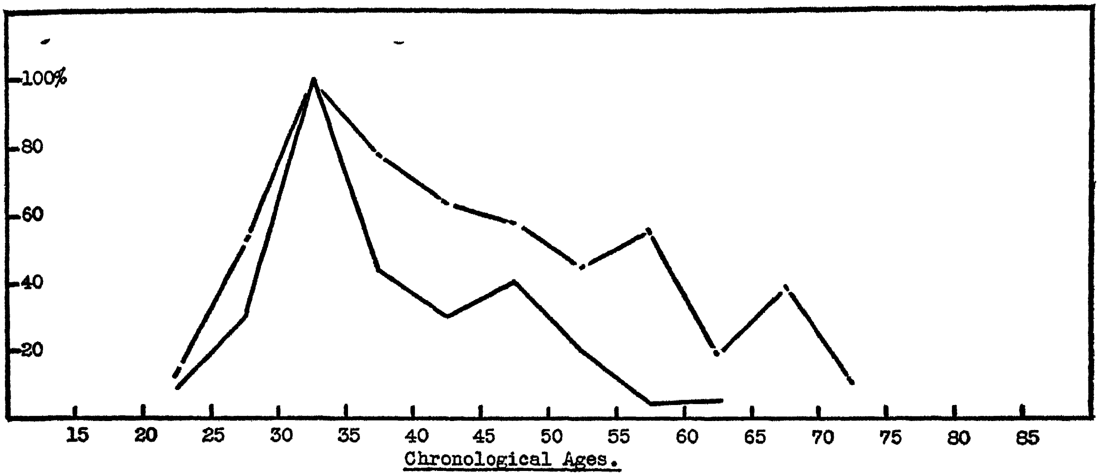


FIG. 4. AGE VERSUS PRODUCTION OF SHORT STORIES
Solid line, 87 SUPERIOR SHORT STORIES BY 38 AUTHORS, NOW DECEASED, AVERAGING 2.29 PER PERSON.
Broken line, 416 SHORT STORIES OF LESSER MERIT BY THE SAME 38 AUTHORS, MEAN 10.95 PER PERSON.

erable degree of certainty that man's productive prime for short stories of the highest excellence has really been ascertained.

Hymn Poems. The solid line in Figure 5 sets forth age data regarding the one best-loved poem, sung to church hymn tunes, written by each of 63 poets, now deceased. No poem was used in constructing the solid line unless it appeared in 10 or more of 20 church hymnals that were canvassed. And none was used unless it appeared in more hymnals than any other poem by the same author. The broken line presents like information regarding the composition of 298 other poems written by the *same 63 poets.* All the age data set forth in Figure 5 were obtained from a composite list.

It will be noted that the peak for quality of output occurs at ages 30 to 39, inclusive, and that the peak for quantity of output occurs ten years later. All these curves seem to refute the idea that genius functions equally well throughout the years of adulthood. But, of course, these findings are merely group averages and they are not directly applicable to all individuals. As is well known, some persons have made their most valuable contribution when past seventy years of age, and others have done very notable work while still in their teens. In addition one should bear in mind that

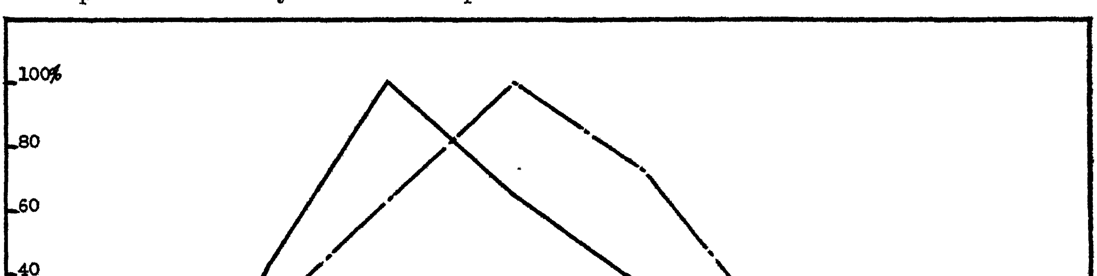


FIG. 5. AGE VERSUS PRODUCTION OF POEMS SUNG AS HYMNS
Solid line, THE ONE BEST-LOVED POEM BY EACH OF 63 PERSONS WHO WERE BORN FROM 1800 TO 1849.
Broken line, 298 SIMILAR POEMS OF LESSER POPULAR APPEAL WRITTEN BY THE SAME 63 INDIVIDUALS.

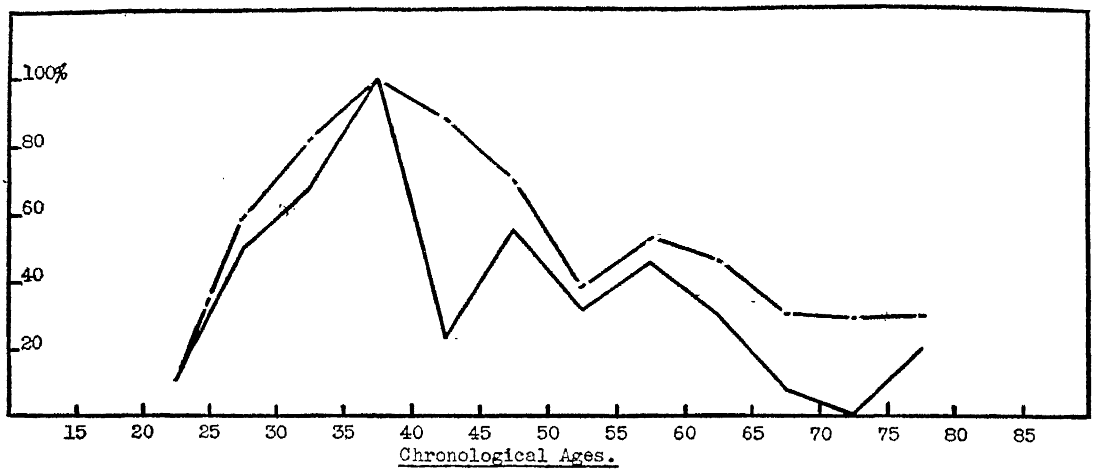


FIG. 6. AGE VERSUS PRODUCTION IN EDUCATIONAL THEORY AND PRACTICE
Solid line, ONE SUPERIOR CONTRIBUTION BY EACH OF 75 PERSONS WHO WERE BORN FROM 1750 TO 1850. *Broken line,* 425 CONTRIBUTIONS OF LESSER QUALITY FROM 206 INDIVIDUALS BORN FROM 1750 TO 1850.

throughout almost their entire lives very superior individuals may do work of higher quality than the very best work that is accomplished by men of lesser talent. The mere fact that a man has passed his own productive prime does not signify that he will no longer produce work of very great value to society.

Education. The solid line of Figure 6 shows the ages at which each of 75 individuals, now deceased, produced his one most frequently cited educational treatise, report, or plan for the improvement of educational practice. No contribution was used unless it was cited and discussed in 3 or more of 49 histories of education that were employed as sources of information. The broken line sets forth information regarding the production of 425 educational contributions by 206 persons, now deceased. The period of maximum production is the same in both curves.

Economics and Political Science. In books which deal with the history of economics and political science there is so much overlapping of these two fields that it seemed inadvisable to attempt to separate them. The solid line in Figure 7 presents for both economics and political science, therefore, the one most frequently cited book by each of 62 men, now deceased. No work was included unless it

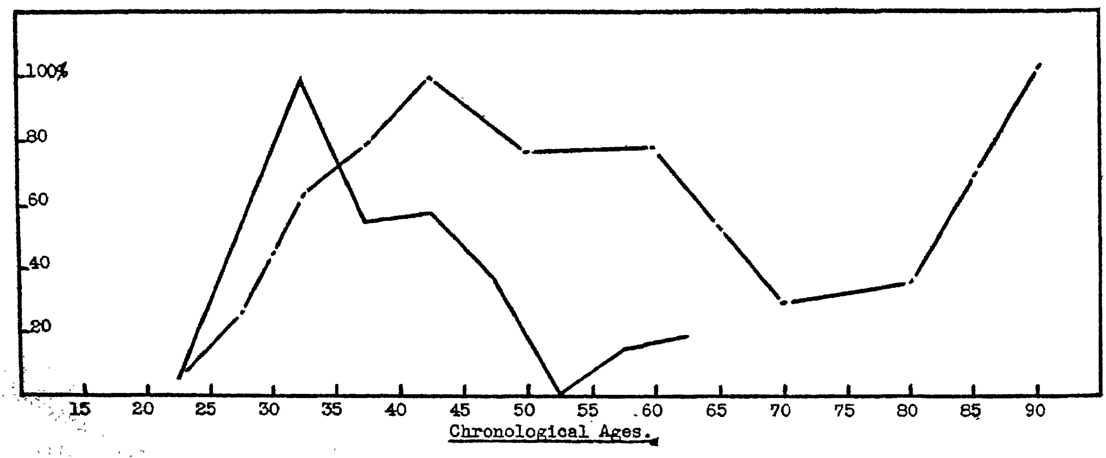


FIG. 7. AGE VERSUS PRODUCTION IN ECONOMICS AND POLITICAL SCIENCE
Solid line, ONE SUPERIOR CONTRIBUTION BY EACH OF 62 INDIVIDUALS BORN BETWEEN 1750 AND 1850. *Broken line,* 234 OTHER CONTRIBUTIONS OF LESSER SIGNIFICANCE WRITTEN BY THE SAME 62 PERSONS.

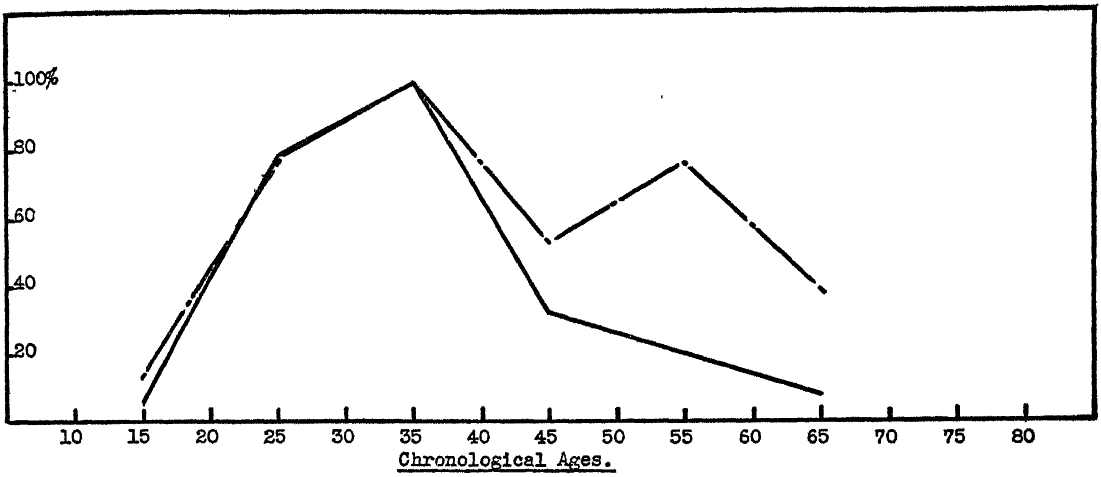


FIG. 8. AGE VERSUS PRODUCTION IN MATHEMATICS
Solid line, 42 SUPERIOR CONTRIBUTIONS FROM 27 MATHEMATICIANS WHO WERE BORN FROM 1748 TO 1848. *Broken line,* 169 OTHER CONTRIBUTIONS OF LESSER IMPORTANCE PRODUCED BY THE SAME 27 INDIVIDUALS.

appeared in 5 or more of 20 histories of economics and political science that were canvassed. The broken line presents for the *same 62 deceased men* the ages at which they either wrote or first published 234 other works in the same fields of endeavor. It is again apparent that quantity of output continued to appear at later age levels than did work of the highest quality.

Prior to constructing the broken line in Figure 7, the present writer submitted the solid line to a college dean and asked his opinion as to why this curve for output of high quality attains its peak at such a relatively youthful age level and descends so rapidly thereafter. The dean suggested that men are likely to possess more time for doing creative work when they are young. By way of illustration he stated that as a young instructor he was less preoccupied than he is at present; now his hands are so tied by administrative duties that he can find no time at all for creative endeavor.

Mathematics. In Figure 8 the solid line is based upon 42 mathematical contributions by 27 mathematicians,[8] now deceased. The broken line presents the ages at which a total of 169 contributions were made by these *same 27 mathematicians.*[9] Although in their ascents the two curves in Figure 8 almost coincide, the curve for the larger number of contributions sustains itself much better at the older age levels.

Invention. In an article[10] entitled "Age of Production in Invention and Other Fields," Wyman asserts that for the 20 greatest inventions of modern times, the average age of the inventors at the time of making their notable inventions is 32. He adds that, if the list is enlarged to include the 40 greatest inventions, the average age of the inventors rises to 33.3 (see the solid line in Figure 9). He says also that, if the list is still further enlarged to include the 80 greatest inventions, the average age of production moves up two more years.

Although one may doubt that Wyman is able to measure the importance of a particular invention with as much precision as his statements imply, the age-curves that are presented herein suggest, nevertheless, that Wyman's foregoing assertions contain an element of solid truth. By assembling a list of 554 great inventions, the present writer went one step further in his calculations than Wyman did and found that the average age of the inventors moved upward still farther than Wyman's highest average, namely, to 36.71 years (see the broken line in Figure 9).

The reason why inventions of slightly less than the very highest quality are more likely to appear beyond, rather than before, the optimum age of 32 is more easily understood after inspection of the age-curves presented herein. The average person seems to develop to the peak of his efficiency much more rapidly than he descends therefrom. Therefore,

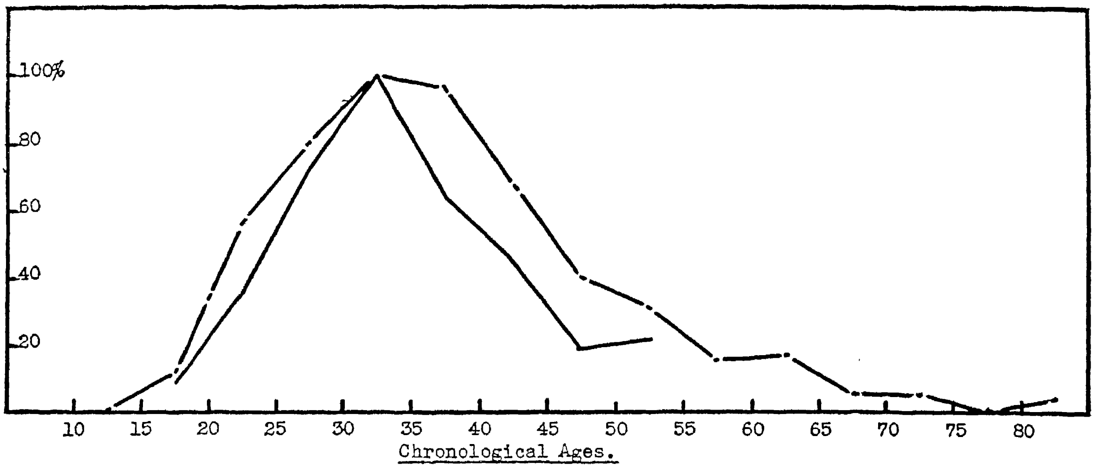


FIG. 9. AGE VERSUS PRODUCTION OF PRACTICAL INVENTIONS
Solid line, 40 GREATEST PRIMARY INVENTIONS OF MODERN TIMES PRODUCED BY 35 MEN NOW DECEASED.
Broken line, 554 INVENTIONS OF LESSER SIGNIFICANCE PRODUCED BY 402 INDIVIDUALS NOW DECEASED.

the period beyond that of peak efficiency is likely to be both of longer duration and also much more productive as regards sheer quantity of output than is that very much shorter interval of time during which man is "on the make," so to speak.

But Wyman's finding with reference to the ages of inventors is an insufficient basis upon which to generalize, and Wyman wisely refrained from doing so. The present writer has found that the average age of a group of contributors of works of less than the highest merit may be older than, younger than, or exactly the same as the optimum age level at which work of the very highest quality tends most often to appear. As regards age variability among contributors, the findings are much more consistent. For athletes,[11] and for creative thinkers of many kinds—scientists, philosophers,[12] authors[13] of "best books," painters[14] in oil, and others, the very best achievements are executed at ages which deviate less from the optimum age level for accomplishing than do performances of lesser average merit.

Hymn Tunes. It is also true that the one most outstanding work of each of the most brilliant creative thinkers is likely to be accomplished during a narrower age range than is the one most notable work of each of the less renowned creative thinkers. For example, each of the three curves of Figure 10 presents the ages at which the most popular church hymn tunes were composed by each of 131 individuals segregated upon the basis of the popularity of their one best-liked hymn tune. The data were assembled by Mrs. Ruth Burt Korb as part of her Master's Thesis. The solid line presents age data for those composers whose one best-loved hymn tune appeared in 10 or more of 20 church hymnals that were canvassed by Mrs. Korb; the broken line presents age data regarding other composers whose one best-loved hymn tune appeared in from 4 to 9 church hymnals, and the dotted, or dash, line sets forth age data for still another group of composers whose one best-liked hymn tune appeared in from 1 to 3 church hymnals.

Although each of the curves attains its peak at ages 30 to 39, inclusive, the curve which presents age data for the most popular group of compositions exhibits a sharper peak and also a narrower range than does the curve which presents data for the least popular group of hymn tunes (the dash line). The fact that the two curves of Figure 10 which set forth age data for the less popular groups of hymn tunes each persist until beyond age 70 suggests that, although a hymn tune that is either written or first published beyond age 70 may be a particular composer's one best hymn tune, such a tune is not likely to be chosen for publication in many church hymnals. Since the foregoing phenomenon has been found to occur in several different fields of endeavor, it seems

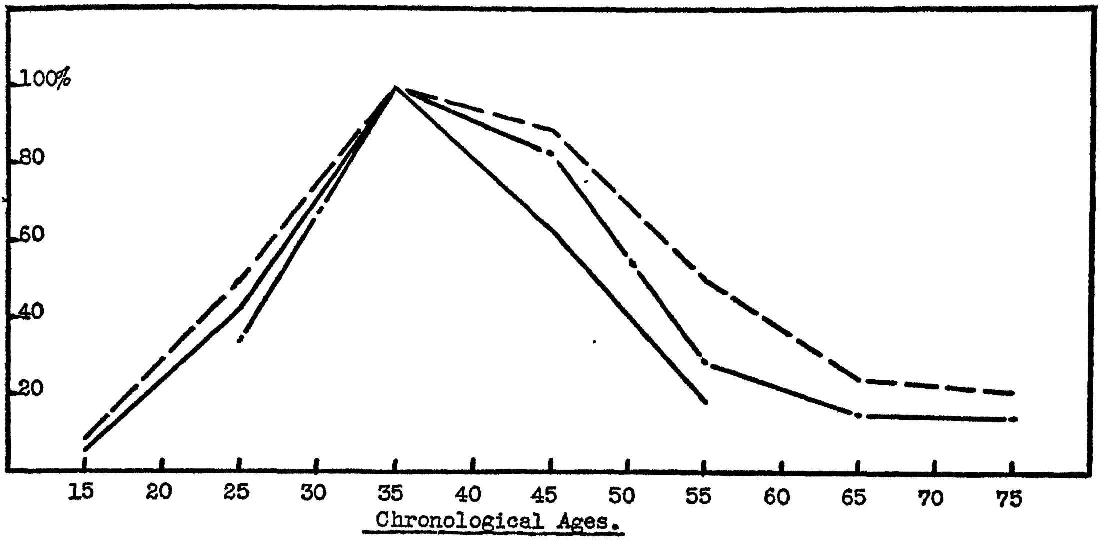


FIG. 10. AGE VERSUS PRODUCTION OF HYMN TUNES
THE ONE BEST-LOVED HYMN TUNE BY EACH OF 131 COMPOSERS, BORN FROM 1815 TO 1850. THESE TUNES ARE PLACED IN THREE CATEGORIES OF POPULARITY: *solid line,* 42 FOUND IN 10 OR MORE OF 20 HYMN BOOKS; *broken line,* 51 FOUND IN 4 TO 9 OF THE SAME HYMNALS; *dotted line,* 38 FOUND IN 1 TO 3 OF THE SAME.

reasonable to conclude that the best and most brilliant creative accomplishments are the work of individuals who "hit their stride" at not too old an age level.

Chemistry. In Figure 11 the solid line presents age data for 52 very superior contributions which are listed in Hilditch's *A Concise History of Chemistry,*[15] and which also were selected by two out of three university chemistry teachers as among the 100 greatest contributions to chemistry of all time. The broken line presents age data for 993 contributions, all of which were regarded by Hilditch as of sufficient importance to warrant their inclusion in his history of chemistry. The dash line sets forth data for 6,743 contemporary contributions (articles, patents, and books). Age data regarding the contemporary contributions were obtained in

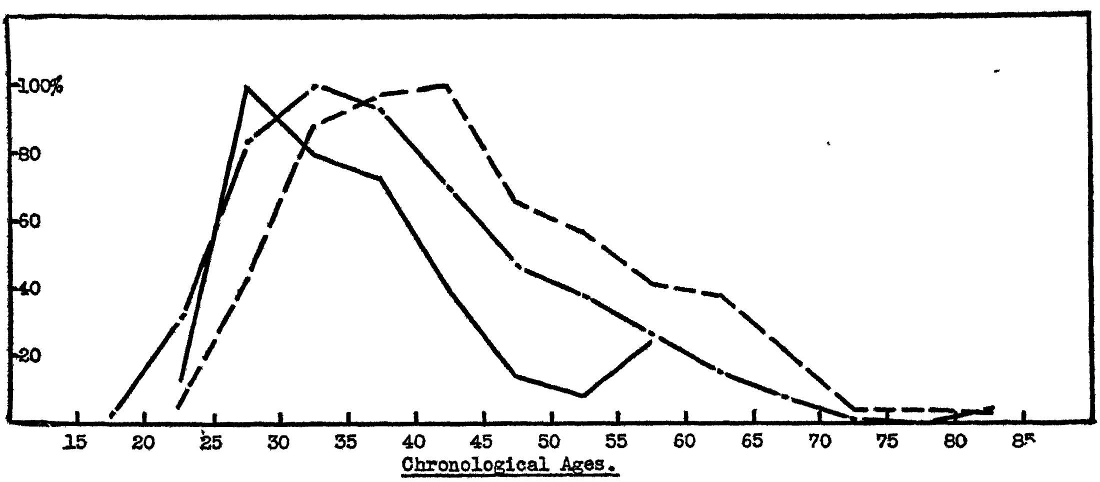


FIG. 11. AGE VERSUS OUTPUT IN CHEMISTRY
Solid line, 52 OF THE GREATEST CHEMICAL DISCOVERIES, MADE BY 46 MEN NOW DECEASED. AVERAGE 1.13.
Broken line, 993 CONTRIBUTIONS OF LESSER MERIT MADE BY 244 CHEMISTS NOW DECEASED. AVERAGE 4.07.
Dotted line, 6,743 RUN-OF-THE-MINE CONTRIBUTIONS BY 1,136 CONTEMPORARY CHEMISTS. AVERAGE 5.94.

the following manner. The names of the contemporary chemists and their birth dates were found by canvassing the 1933 edition of *American Men of Science*[16] from the letter A to Gr, inclusive. A sample of the contributions of these contemporary chemists was then obtained by canvassing *Chemical Abstracts* for the years 1920 to 1922, inclusive, and also for the years 1930 to 1932, inclusive.

In several respects Figure 11 reminds one of Wyman's assertions with reference to the ages at which great inventions are most likely to be made. Thus, the curve which presents age data for the 52 contributions of the highest merit ascends most rapidly, attains its peak earliest, and falls off earlier than do either of the other two curves. The curve in Figure 11 which presents age data for contributions assumed to be of the least average merit rises latest, attains its peak latest, and also falls off later than do either of the two other curves in this figure.

One might conclude that the "brainiest" chemists tend to use their brains with maximum effectiveness at the earliest opportunity. This tendency on the part of scientific giants to develop to the peak of their efficiency at relatively youthful age levels presents a baffling problem to the investigator who wishes to ascertain with great precision man's one most creative year. Any study that concerns itself with achievement of the very highest quality must of necessity include a very restricted number of achievements within each separate field of endeavor. But, the smaller the number of cases, the larger the probable error and, hence, the less trustworthy the finding.

It is true, to be sure, that for the contemporary contributions two time-lags occurred between date of achievement and date of appearance in *Chemical Abstracts*. But, since citation in *Chemical Abstracts* occurs usually within less than a year subsequent to first publication, it seem unlikely that difference in time-lag can account entirely for the relatively late age levels at which contemporary contributions are being made in chemistry.

Some may wonder whether the curves in Figure 11 may not merely indicate that epoch-making discoveries in the field of chemistry are being made today at older age levels than was formerly the case. With this possibility in mind the writer made an exhaustive analysis of the three sets of data obtained by requesting three university chemistry teachers to select the 100 greatest chemistry contributions of all time. It was found that 50 per cent of those born from 1820 to 1850 had made their outstanding contributions at slightly younger, but not significantly different, average ages than had the chemists born earlier.

Since the more recently born chemists have not made their most notable chemistry contributions at older average age levels than the earlier born chemists, why do the three curves in Figure 11 ascend in the order indicated rather than in the reverse order? If the drive to accomplish weakens with advancing years, this in itself may be an indissociable age effect. If so, it is idle to argue that the fifty-year-olds *could* have attained a better average output than the thirty-year-olds if the former had wanted to do so badly enough. It is likewise idle to argue what might have happened under any other hypothetical condition which conceivably might have existed but which actually did not exist.

Conclusions. Study of the graphs presented herein seems to justify the following tentative generalizations. (1) Within any given field of endeavor, not one only, but numerous age-curves can be constructed which show the rise and fall of creative output at successful age levels. (2) The shape of any one of these various curves is in part a function of quality of performance. (3) As compared with an age-curve which sets forth quantity of performance at successive age levels, the peak of a curve which presents age data for performances of the highest quality is likely to be more narrow or pointed. (4) Within any given field of endeavor, quality of output and quantity of output are not necessarily correlated, output of the very highest merit tending to fall off at an earlier age level than does output of lesser merit. (5) Since quality of output and quantity of output are imperfectly correlated, no very accurate comparison of the ages of greatest creative efficiency in the several fields of science can be made unless the contributions are first equated upon the basis of their quality.

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ERYTHROS

From marrow web, its nuclear center lost
As it was born into the plasmal flood,
A hemoglobin-bearing disc of blood
Begins a restless journey through its host.

Equipped to carry pulmonary aid
To cells in want of oxygen
On many metabolic fronts and lend
Its bulk to keep the capillary grade.

A thousand circuits daily for one moon
To splenic journey's end or Kupffer's aisle
By trillions fragile shells reduced to bile,
A bitter souvenir of verdant doom.

Itself not living, symbolizing life
In "blood will tell" or other genic phrase
As culled from records of an endless fight,
A plastid form ubiquitously rife,
Subservient, efficient, clad in lucent grace,
The thermic mammal's blond erythrocyte.

—JOHN G. SINCLAIR

SCIENCE ON THE MARCH

FOSSIL PIGMENTS*

BIOCHEMICAL chapters of the ancient past are suggested by the presence of numerous organic pigments of well-defined properties in natural deposits of thousands of years' standing. Chlorophylls occur throughout the world of green plants, accompanied by the red, orange, or yellow fat-soluble members of the carotenoid series, whose colors are masked in green leaves and in many unicellular algae, but are familiar to all as extravagantly displayed in many flower-parts, fruits, certain autumn-colored leaves, and in some roots, such as the carrot. Many carotenoids are synthesized also by bacteria and fungi. Pigments of the same class are assimilated from food and stored in the skin, liver, fat, milk, eggs, and other tissues or products of innumerable animals. Many carotenoid compounds are present in the vast populations of microscopic plankton organisms of the sea, and are conspicuous also in various tissues of the larger plants and animals found there. It was the impressive display of carotenoids in many obligately carnivorous or detritus-feeding animals of the ocean's unlighted depths, destitute of living photosynthetic plants, which gave the initial impetus to the writer's search for supplies of such pigments in bottom sediments.

In natural deposits of moderately great age, such as those of certain moor soils, muds from lakes, marshes, underground caves, and notably deep-lying sediments of the ocean floor, molecular fragments of chlorophyll and of animal homologues, such as the hemin of hemoglobin, still persist as various porphyrins. These occur side by side with various carotenoids, although the marine carotenoids appear to decrease with age (depth of stratum) just as does total organic matter.

In organic fossils of great ages (e.g., petroleum, shale oils, and coal) porphyrins occur, but are no longer accompanied by carotenoids, these having been long since oxidized, or, under appropriate conditions, perhaps reduced to colorless hydrocarbons.

Thus, progressing from living material to fossil substances of increasing age, complex molecules such as chlorophyll and hemin are the first pigments to undergo degradation, persisting for but a very short time after the death of organisms; carotenoids are represented in anaerobic deposits of great age in a biochemical sense, i.e., thousands of years, antedating even the Pyramids of Egypt; and these intermediary fossils are in turn outlasted by the porphyrin fragments of the original more complex pigments; some of these porphyrins persist into eons of geological time. Various chlorophyll- and hemin-derivatives in bituminous rocks, petroleums, mineral waxes, asphalts, and other fossilized materials have been extensively discussed by others. The present discussion is concerned primarily with the occurrence of carotenoids in sediments recovered from ancient burial in the bottom of the sea.

Let one haul up a solid cylindrical column of mud, collected from the ocean floor with a special coring device, draw off the superficial water, submit the sample preferably to further drying in an evacuated container, and subsequently treat the material repeatedly with appropriate organic solvents such as acetone or alcohol. The filtered extracts show deep green-brown, greenish orange, or yellow colors depending on the proportions and relative concentrations of chlorophyll break-down products and carotenoids present. No unaltered chlorophyll is encountered, but numerous derivatives of it are separable. A number of different carotenoids are always present, including hydrocarbons of the $C_{40}H_{56}$ series, and so-called polyene alcoholic or ketonic derivatives, wherein from one to six or more oxygen atoms have entered the molecular constitution to give $C_{40}H_{56}O$, $C_{40}H_{56}O_2$, etc.

The carotenoids as a class are chemically unstable, their crystals or solutions undergoing ready bleaching by atmospheric oxygen. This destruction is enhanced by the presence of light and by elevated temperatures. Carotenoids are also destroyed by acids and in some cases by alkalies. The natural preservation of such ordinarily labile

* Contributions from the Scripps Institution of Oceanography, New Series No. 239.

compounds over vast ages of time is less surprising, however, when one considers the very special conditions prevalent in buried strata of the ocean's floor. For there, free oxygen is lacking, light is absent, temperatures perpetually approach 0° C., and approximate neutrality, approaching that of body fluids, persists. And, while native chlorophylls are readily broken down to their still-pigmented residues by ordinary chemical or biochemical processes, carotenoids are altered or absorbed in the digestive tracts of most animals only at low levels of efficiency. Thus they may pass again and again through the alimentary canals of various mud-eating animals in a chemically unaltered state. Even those which are assimilated may be stored in the consumers' tissues in a but slightly modified or unchanged condition. Furthermore, carotenoids are relatively refractory toward the ordinary nonoxidative biochemical processes of such environments.

The ultimate food supply of benthic animals is in the slow, ceaseless rain of organic matter from lighted zones above. The constant manufacture and supply of carotenoids by diatoms, dinoflagellates, and other marine photosynthetic plants and by certain fungi and bacteria, exceeds the power of animals and microorganisms to assimilate or destroy these pigments. Hence certain parts of the sea bottom have become vast reservoirs for such compounds, which are gradually buried under conditions favoring their preservation over centuries of time.

Preliminary quantitative studies have revealed that, while finely suspended marine detritus may contain as much as 50 mg. of total carotenoids per 100 grams dry weight of material, or 165 mg. of carotenoids per 100 grams of ash-free organic matter involved, marine sediments off the coast of southern California yield amounts of the general order of 0.25 mg. per 100 grams of dry mud, or roughly 10 mg. per 100 grams organic matter in such sediments. This mean figure approximates those of investigated sediments lying 106, 650, and 1,096 fathoms beneath the ocean surface, and to mud strata varying in age between about 15 and 2,500 years. The same pigments have been demonstrated in far older deposits as well. The pigments seem to be present at slightly higher concentrations at the top of the mud than in the deeper-lying strata, and this is to be expected, since any processes of decomposition will have been operative longer in the older material.

Quantitative and qualitative variations are encountered. At one station, for example, material collected from the surface of the ocean floor under 106 fathoms of water, yielded 0.17 mg. of carotenoids per 100 grams of dried material; the first, second, and third foot of a vertical core collected there, representing accumulations of not more than 200, 400, and 600 years respectively, yielded 0.24, 0.06, and 0.05 mg. per cent; the fourth foot of this core, representing an estimated maximal age of 800 years, appeared to contain only about 0.03 mg. per cent. On the other hand, sediment collected at a point not far distant, at a depth of 650 fathoms beneath the water surface yielded, from the eight-foot mud-depth of the core (estimated age = 2,500 years) 0.29 mg. per cent of the carotenoid material. One core, collected from the bottom of the Gulf of California at a depth of 364 fathoms, was 17 feet long. A section of this column of mud, cut from the 15- to 16-foot depth, yielded some 0.61 mg. per cent of carotenoids from the 6,000 to 7,000-year-old stratum.

All marine sediment cores yield greenish porphyrin derivatives as well as carotenoids, the more rapidly deposited material in the Gulf of California being substantially richer in both types of molecular fossil. One core of oceanic sediment was remarkable in its pigmentary stratification. While carotenoids, accompanied by greenish porphyrins, were recovered from the 6-inch, 74-inch and 80-inch depths of this sample (representing approximate respective ages of 600, 7,000, and 8,000 years), an intermediate section of the same sample, taken at the 44-inch depth (about 4,000 years old) contained the greenish porphyrin common to all the sections (absorbing light in the red region of the spectrum at about 669 mμ in petroleum ether), but unaccompanied by any carotenoids. Instead, an oily fraction was encountered, containing a yellowish pigment showing blue-green fluorescence, closely similar in this respect, in spectral absorption and in critical

chemical behavior to a pigment obtained from a sample of California crude petroleum, and similar also to a porphyrin from asphalt.

Perhaps equally as arresting as the fact itself of age-long preservation of carotenoids are the qualitatively selective processes which become evident on chemical examination of the constituent pigments. For, while the xanthophyllic or oxygenated type of carotenoid is greatly preponderant over the hydrocarbon or carotene class in all terrestrial and marine green plants, as well as in the vast majority of marine animals, the proportionality has undergone a reversal in the fossil domain. As examples, various seaweeds may contain carotenes in the order of from 5 to 25 per cent of total carotenoids; microscopic dinoflagellate plants such as *Prorocentrum micans,* and diatoms such as the common *Nitzschia closterium,* both of which occur in vast numbers in the sea, have been found to yield only about 10 per cent of their total carotenoids as carotene, the remaining 90 per cent belonging to the oxygenated or xanthophyllic class. Again, the stores of carotenoids in finely suspended marine detritus or "ocean refuse" are approximately 90 per cent xanthophylls. The great majority of marine animals examined to date reveal their capacity to store carotenoids of the xanthophyllic class with a high degree of selectivity. Indeed, numerous fishes, mollusks, and echinoderms, for example, contain xanthophylls or their chemical esters exclusively, rejecting carotenes in their feces or otherwise disposing of these pigments instead of storing them.

Turning back to the sediments, we encounter there proportions of the hydrocarbon carotenoids ranging from 35 to 40 per cent in the topmost layers of mud, to 70, 80 and even nearly 90 per cent in deeper strata. The 2,500-year-old sample, for instance, yielded 83 per cent of its carotenoids as carotenes, and, in the 6,000- to 7,000-year specimen from the long Gulf of California core, carotenes exceeded xanthophylls by a ratio of more than 2 to 1.

Chemical investigations have indicated that the chief member of the carotene class in marine sediments is the common pro-vitamin A compound, beta-carotene, with pigments resembling alpha-carotene in secondary prominence. These are frequently accompanied by other hydrocarbon types of carotenoid.

Among the xanthophylls of marine muds, compounds not readily distinguishable from the common pigment zeaxanthin, encountered notably in yellow Indian corn, are the most common. These sedimentary pigments are probably identical with certain newly described xanthophylls occurring in diatoms and other marine plants. Fucoxanthin, common in kelps and other algae, is abundant in sedimentary material, as are other less common xanthophylls from algae. Sulcatoxanthin, or peridinin, occurring both in some of the microscopic algae and in certain sea-anemones, is another xanthophyll found prominently in sediments.

The general preponderance of carotenes over xanthophylls in long-standing marine deposits constitutes a reversal of the status prevailing in the great majority of marine organisms. This condition in sediments may have its explanation in several potential factors. In the first place, xanthophylls are more readily oxidized and bleached by atmospheric or dissolved oxygen than are carotenes. While this differentiative influence might be operative even in the deeper realms of the ocean's water, it would not apply beneath the surface of the oxygen-free mud. Secondly, the majority of marine animals investigated store chiefly xanthophylls rather than carotenes in their tissues; their storage and partial degradation of polyene alcohols, with fecal rejection of carotenes could contribute substantially to a gradual preponderance of the latter class of carotenoid in bottom sediments. Finally, there are indications that certain kinds of bacteria and allied microorganisms living in marine muds may contribute carotenes of their own synthesis, and that other such flora may be able to effect the chemical reduction of xanthophylls to compounds of decreased oxygen content, or perhaps even to carotenes.

These ancient biochromic compounds, including porphyrins and carotenoids, together with accompanying oil-soluble substances, may be looked upon as diagnostic features in the continued search for biochemical processes operative in the genesis of petroleum and allied natural deposits.—Denis L. Fox.

BOOK REVIEWS

PLASTIC HORIZONS

Plastic Horizons. B. H. Weil and Victor J. Anhorn. 169 pp. Illus. $2.50. 1944. The Jaques Cattell Press, Lancaster, Pa.

WHILE this modest volume (150 pages) suffers in a few places from the technical man's traditional difficulty in converting his scientifically calibrated thoughts into easy and sparkling phrases intriguing to the lay reader, it is on the whole a very readable, well-planned, and carefully executed work.

Divided into five sections, the first, dealing with the various types of plastic materials, their history, chemical formulation, and most prominent characteristics, may prove somewhat cumbersome to the person of little or no chemical knowledge, but it is valuable and necessary to an adequate understanding of the subject. The authors have, on the whole, done an excellent job in simplifying some extremely complex material. Freed of this necessary groundwork, the volume rides much more easily through a general picture of the plastics industry, its problems and accomplishments, military and civilian applications of plastic materials, synthetic fibers and synthetic rubbers, and the prospects for plastics in the postwar era.

While semitechnical books on the subject of plastics have become numerous during the past few years, the sincerity with which Messrs. Weil and Anhorn have attacked the problem is outstanding. Not content with the usual "cataloging" of plastic materials supplemented with a few historical notes and predictions, the authors of *Plastic Horizons* have carefully traced the complex network of economics, technical problems, availability of and competition for raw materials, patent restrictions, and innumerable other factors which have influenced the development of the plastics industry to its present state, and which will guide the course of these materials and their manufacturers in the future.

The volume also takes up at some length the various synthetic fibers and synthetic rubbers, their sources, qualities and potentialities, and their kinship to plastics, a relationship not generally appreciated.

As to the future, the authors make some very sound predictions which, as a matter of fact, scarcely need stating for readers who have at this point become so thoroughly familiar with the plastics field, in its broadest sense, that they should have almost unconsciously arrived at these same conclusions. This, perhaps, is the test which reveals the inherent worth of the book.

While this volume would benefit substantially by the addition of a few well-selected photographs, it does contain a number of excellent charts and diagrams which are of greater intrinsic merit. Valuable as a reference is an appendix listing approximately three hundred plastic trade names and indicating their basic chemical type and manufacturer.

Plastic Horizons should serve well as a reference, as a beginning text, and as a worthy addition to the bookshelf of any layman who would have more knowledge of the plastics picture than the shallow ability to recite names and formulas.—L. H. WOODMAN.

PIONEER GEOLOGIST

David Dale Owen, Pioneer Geologist of the Middle West. Walter Brookfield Hendrickson. Illustrated. xiii + 180 pp. $2.00. 1943. Indiana Historical Bureau.

A HUNDRED years ago David Dale Owen was one of the leading geologists of the United States. He was of the second generation of scientists who made New Harmony, Indiana, their home. He was a son of Robert Owen, the well-known industrial and social reformer, and followed the trail blazed by such men as William Maclure, Thomas Say, Gerard Troost, and Charles Alexander Lesueur. Although David Dale Owen was a chemist of no mean accomplishment, it was as a geologist that he made his claim to fame. He was born near New Lanark, Scotland, June 24, 1807. He was educated in Scotland, England, and Switzerland and specialized in mathematics and science. He came to America in 1828, and was graduated as doctor of medicine in 1837 from the Medical College of Cincinnati. In the same year he was married to Caroline Neef. Shortly thereafter he became connected with the State geological survey of Tennessee under

Gerard Troost, was State geologist of Indiana in 1837–38, and made surveys of the Dubuque and Mineral Point districts of Iowa and Wisconsin in 1839–40. In 1847 he was appointed United States geologist and was directed to make a survey of the Chippewa land district. In 1854, he was appointed State geologist of Kentucky; in 1857, State geologist of Arkansas; in 1859, he was appointed for the second time State geologist of Indiana. He died at New Harmony, Indiana, November 13, 1860. During his lifetime, in charge of pioneering surveys of three states and three territories, he gave the world the first connected picture of the rock structure and the mineral wealth of the Upper Mississippi Valley and laid the groundwork for later geological investigation. Although he was well and favorably known to his fellow geologists and to contemporaries interested in the natural resources of the middle western United States, Dr. Owen's name and deeds are not now so well known to most present-day students. It is the purpose of this biography to revive his memory and to give him his rightful place in the history of science. Biographies of America's lesser scientists are all too few, and the history of scientific advance in the United States can never be fully told or entirely understood until we know more about the numerous, hardworking, modest men like Dr. Owen, who devoted their lives to scientific research. American science is indebted to Professor Hendrickson and others like him who from time to time have made biographical contributions such as this to its records.—J. S. WADE.

MIDDLE AMERICA

Middle America. Charles Morrow Wilson. 317 pp. Illus. $3.50. 1944. W. W. Norton & Co., Inc., New York.

MR. WILSON has been writing on our neighbors to the South for some time and *Middle America* is probably his most ambitious attempt. He sets out to tell us about these nearest neighbors because of their significance to us. Thirty-seven million Americans living in an area a third the size of the United States who are, as Mr. Wilson states it, by odds our best customers, require more understanding than we have applied to them in the past. The extent to which we depend on this area for quality coffees, bananas and sugar and the extent to which we could draw on them for rubber, rotenone insecticides, quinine, and other tropical products, are factors in our national life and international policy which we cannot continue to neglect.

Mr. Wilson treats us to a travelogue in space and time covering lands, people and history, and forecasting the future of the millions who live in the Mexico-Colombia-Cuba tropical triangle. The author continually ties his observations to the enlightened self-interest of the United States, and does a good job of developing the theme that the welfare of our neighbors is in a real sense our welfare.

In the conglomeration of races that are the Americas, Mr. Wilson emphasizes properly the predominance of Indians. Their culture, their abilities, are sketched in bold if not always definite strokes, and their desires are in this case not neglected. A brief sketch of the biography and economy of each one of the countries leaves us wanting more, but stimulated by the partial picture. The two chapters on crops tell dramatically the story of the influence on civilization of crop movements. They point to potentialities and sometimes apparently fall into wishful thinking. In these chapters particularly, the book suffers from the lack of a critical blue pencil. However, our past interest has extended mainly to purchasing tropical crops. Few in the United States know these plants intimately. It is perhaps understandable that the author was unable to achieve a high standard of accuracy in his statements. For example, those who know, will be annoyed by references to "ergot root" on page 141. However, the true nature of ergot is indicated on page 147. Those who want to know how derris is propagated, or where allspice came from, and such, should look elsewhere than in Mr. Wilson's yarn.

The discussion of transportation carries the airplane into a role more important than most will predict for it. But the general impression given to the effect that the airplane, and other forms of improved transportation are, and will be, central in determining the advance of agriculture, commerce, and human welfare in these tropical

regions, cannot be denied. The health menace of tropical diseases to Middle America and to us is strongly put, and deserves all the emphasis given.

After reading this fast-moving story, and appreciating its sense of mission, one wishes that Mr. Wilson would apply his writing ability in a further work, the facts of which would be made the responsibility of those who have time to know thoroughly.—RALPH R. ALLEE.

"ECCE IN DESERTO"

The Gobi Desert. Mildred Cable with Francesca French. 303 pp. Illus. $3.50. 1944. The Macmillan Co., New York.

ONE does not need to have trekked over the ancient trade routes across China to know that this is a good book and one of great sincerity. Since most of us civilians these days must take our travel vicariously, it is comforting to be reminded that a few books like this one, which attains a high degree of literary excellence as well as factual dignity, are being published at a time when so much opportune but ephemeral and obviously "trumped up" war stuff seems to be the order of the day.

Mildred Cable, a Protestant itinerant English missionary, has lived for more than twenty years in the province of Shansi in North China. Five times, in the course of her work with the China Inland Mission, she traversed the whole length of the Gobi Desert. With her two companions, Eva and Francesca French, she traveled northwestward past the Barrier of the Great Wall and "into the country that lies beyond"—terrifying in its magnitude, awe-inspiring in its antiquity and wisdom. "From Etzingol to Turfan, from Spring of Wine [Suchow] to Chuguchak, we spent long years in following trade-routes, tracing faint caravan tracks, searching out innumerable by-paths and exploring the most hidden oases. . . . The caravan men knew us, carters hailed us as old friends and oases dwellers welcomed us to their homes. . . . Once the spirit of the desert had caught us it lured us on and we became learners in its severe school. The solitudes provoked reflection, the wide space gave us a right sense of proportion and the silences forbade triviality."

Miss Cable's achievement, in setting down her experiences among the peoples and places of the Gobi, is that she has successfully avoided the aridity of the usual travelogue. This, of course, is no facile literary trick, but craftsmanship of the most purposeful and artful kind, even though unselfconscious. Her method may be described as topical, as opposed to chronological or Baedekerian. Each chapter becomes an essay—readable and enjoyable by itself. (The chapter on "The Homes of the Desert" should go in the next English-essay anthology.) Yet all the chapters are bound together by a geographical unity, by the sheer impact of the Gobi. It may be significant too that Miss Cable wrote her book while a guest of the Buddhist priest in the Chapel of Meditation on the Lake of the Crescent Moon, on the edge of the Desert of Lob.

The Gobi is made up of many intangible elements—solitude, austerity, desert-ness. But there is also the tangible life of the Gobi, and it is this life, past and present, that claims this traveler's chief attention—the desert tribes, the oasis dwellers, the caravan men, the roads, the homes, the towns, the Moslems and Buddhists, the priests, the caves and temples, the inns, the fortresses, the palaces and gardens, the various languages, the fauna and flora. All are here, though happily they are not readily separable into their scientific ologies; and out of it all emerges that elusive "thing" which the author endeavors ultimately to convey to her readers—the spirit of the Gobi. And, of course, Miss Cable would be no true lover of the Gobi if she did not at least suggest that there is something mysterious in the charm that the desert holds for those who know it—something perhaps indicative of the urge that drives men onward in their eternal quest to conquer the unknown. As Prof. H. A. Beers once put it:

> The wilderness a secret keeps
> Upon whose guess I go:
> Eye hath not seen, ear hath not heard;
> And yet I know, I know . . .

This book is prodigious in its wealth of facts, lore, description, and impression, both of scientific and popular interest. There is much anthropology and geography, some natural history and political history, some

of many things. But for at least one western reader its chief lasting value will be a lesson in humility and a deepening of his respect for the Chinese people and their civilization. Here in the heart of Asia, in what is termed a desert, they have forgotten more perhaps than we occidentals will ever know. They have suffered much; they are bound by traditionalism; yet they are so old and wise. And one cannot help wondering what China may become in our postwar world if freedom for her should really mean freedom.—PAUL H. OEHSER.

FOOD, WAR, AND THE FUTURE

Food, War and the Future. E. Parmalee Prentice. Illus. 164 pp. 1944. $2.50. Harper and Brothers.

THE title points aptly to the major problem of the human race, that of producing enough food so that all may live without hunger and the necessity of struggling with others for a limited food supply.

The first chapter deals with upward trends in population and the need for vastly increased food supplies if the present trends continue. The conditions of want before the 19th century, and the upsurge in production and the well-being of mankind during the 19th century are outlined. The great increase in population in Europe and America during the last century is noted, and the author asks if Europe and America are to share the fate of China, India, and Japan as a result of overpopulation. He points out that:

> There is nothing in Asiatic geography which makes misery unavoidable in that continent, and there is nothing in the geography of Europe and America, nothing in our history, or in the character of our inhabitants, which assures for us the standard of living which we are sometimes told is the birthright of every human being.

The second chapter deals with the abundance that came with freedom of enterprise and improved agricultural practices during the 19th century. Emphasis is also placed on the lack of ability of all but a few to understand that this new condition of plenty would not necessarily continue indefinitely. The author quotes from the *Edinburgh Review*, as follows:

> There is something inexplicable, almost mysterious, in the inability or unwillingness of statesmen, moralists and economists to recognize the truth and inexorable working of the law of population. It almost seems, indeed, as if the refusal of the majority of mankind to recognize this law and its inevitable consequences must be a matter of imposed instinct compelling men to pursue to the end their predestined paths of evolution by ceaseless and ruthless struggle.

Much of the material in this chapter is drawn from other writers who have attempted to analyze trends in population and food production, and their probable effects on the future well-being of the human race. Possibilities for expansion of food production are limited, and the author concludes that:

> Unless numbers can be limited so that America shall not have a population larger than the country can support with the standard of living to which we are accustomed, there can be no hope that we shall be saved from the Asiatic tide of poverty.

The third chapter deals with the possibility of further increase in agricultural production. The author points out that some further expansion of production is possible, but that increases in the supply of food, such as occurred during the 19th century, cannot be anticipated. Future increases owing to improved machinery and methods will be subject to the law of diminishing returns, but all economic additions to the food supply that can be accomplished should be exploited. The author is himself a breeder of dairy cattle and has done considerable thinking and writing in this field, so it is only natural that he should emphasize the part of dairy cattle in increasing food production. As pressure of population becomes greater, man will probably be forced to use less, rather than more dairy and other animal products, but an abundance of animal products is part of the American way of life that we hope to preserve. The author follows his customary vein when he debunks purebred dairy cattle. The term "purebred" is an unfortunate invention, since a degree of genetic purity is implied which cannot exist in practical breeding operations, and the word "purebred," as Mr. Prentice obviously thinks of it, is open to considerable debunking. Also, some of the criticism aimed at purebred cattle associations and at the professors and government workers for their support of his version of the "purebred concept" is justified. The term, "breed" has a rather definite meaning in the minds of most livestock

producers. It is difficult to define, other than as a sub-group within a species, but is usually thought of as a rather uniform group of animals that reproduce with reasonable uniformity. Too frequently, emphasis is placed in uniformity of color and other external characteristics, that have little or no economic importance. But many so-called breeds became so recognized because they had greater economic value for a particular purpose than other animals in an area. Productive characters can be used to define a breed as well as color and shape of horns. Holsteins and Jerseys obviously belong to different populations, on the basis of production of milk and per cent of butter-fat, whether they be labeled breeds or something else. Much of the good germ plasm is now found in the groups of animals commonly referred to as breeds and must be utilized in further genetic improvement, whether that be done by selection within a breed, by crossbreeding, or by some other method. The need of breeding for increased productivity, emphasized in this chapter, is sound. The idea that an animal is good merely because it is registered is obviously open to debunking.

This review is not the place for a discussion of the contributions of animal husbandry workers in federal and state institutions to livestock improvement. Mr. Prentice feels that their efforts, notably in dairy-cattle breeding, have been very disappointing. Many data might be assembled to show the contributions of agricultural workers, even those dealing with dairy-cattle breeding. But such a defense should not be necessary here. Each worker who is conscientiously striving to better the productivity of livestock in America should read this chapter critically and profit by every just criticism that applies to his past efforts.

The fourth chapter is based on the precept that:

> Freedom is the greatest gift which government can bring, and the rarest. It is the source of hope and ambition, of energy and initiative. In America it has brought the abundance for which our country has been remarkable, it makes progress possible and life worth living. If food, and other necessaries of life, are adequate in quantity and variety and if men are free there will be industry. If savings are secure from confiscation and debasement there will be thrift, and an industrious, thrifty people make a prosperous and rich nation.

In the words of Henry Home the author emphasizes that "To every occupation that can give lasting relish, hope and fear are essential," and decries the sudden rise in Great Britain and America of a demand for a protected life. He states "Every nation and every people—if it is to be saved at all—must work out its own salvation. Outside help can provide no permanent rescue from a continuing and ever-growing domestic peril," and "No government is productive. It gets from the people the help it gives to the people, operating always at great expense and with much inefficiency." The author presents his views of how democracy in America should function to best provide a more abundant life, and maintains that the freedoms which the government should protect are freedom of every individual to use his own faculties, eyes and hands and brain, freedom to earn, save and own property and freedom of contract. Many may differ with his views of how government should govern, but there is much to stimulate thought.

In the conclusion, emphasis is placed on the necessity of raising agriculture to a high level of efficiency, keeping prices to consumers low while giving the farmer a generous profit, if our present and future numbers are to be adequately supplied with food.—RALPH W. PHILLIPS.

HAPPY DAYS

Many Happy Days I've Squandered. Arthur Loveridge. 278 pp. Illus. \$2.75. 1944. Harper & Brothers, New York and London.

No, dear Author, not "squandered," but days packed with the most profitable activity in which a naturalist can engage, or write about afterwards for the delight and instruction of all who will read! The reviewer took up this entrancing volume in a hammock swung among some of the choicest glories of New England mountain scenery—and scenery, hammock, and self vanished utterly, while his spirit roamed for three enchanted hours with the author in his adventures with animals of the most diverse description. The book opens with the author as an infant and traces his interest in living

things rapidly up to his departure for Egypt, and later to that naturalist's paradise, tropical East Africa. His boyhood experiences with the "skinning" of a partially putrid python, *"un peu passé"*; his encounter with angry but mystified English game-keepers; his bags of frogs and adders; and the accounts of the trials of his long-suffering but thoroughly understanding parents, should be read and studied by all boys (yes, and girls in these modern days) who have a bent for natural history, and especially by the parents of such!

In tropical Africa—and the reader will actually feel himself there no matter where he happened to be when he picked up the book—there are adventures recorded enough to satisfy the most jaded mind. Spitting cobras, horses painted to resemble zebras, the Author in the character of a dispatch rider for the British Army in World War I, birds whose eggs are glued to the inside of an upside-down nest, invasions by the feared Siafu ants (the "terror by night" Loveridge well calls them), baboons and leopards,—and oh, what lions! The accounts of lions are extended—we are grateful to the Author for this—for they are more interesting we think, than insects and reptiles. Never have we read better accounts of lions, their habits, foods, captures, killings (there is a bit too much killing here perhaps), and especially the first-hand reports of the incursions of lions into native villages—never have we read better accounts, we repeat, but all too short. Leopards are well dealt with too—both in the pages and in the "abandoned rubber plantations . . . two miles west of Kilosa." Reader, you will, I wager, give almost anything to be there, "two miles west of Kilosa!" I was there for half an hour this afternoon, and know whereof I speak!

The book is quietly written, for all its adventure. That is, it is written in a pleasing narrative style, in good English—no cheap slang, no straining after unusual effects, no attempts to be "smart," and "different"—a book written decently and in order, as was *Robinson Crusoe* and the *Vicar of Wakefield*. In other words, an easily read book, a pleasing book, an informing book, a provocative book; provoking one, that is, to pack up and go with the Author "two miles west of Kilosa" or anywhere two miles west of anywhere else, so long as it be with Loveridge!

And now, may the reviewer be permitted to say: first, that the book is too short. The Author should have taken a longer time, and written twice as much. It is "touch and go" with many interesting items that really ought to be dealt with more at length. Second, there should be more illustrations. There are five half-pages containing nothing but blank paper—this is unbearably tantalizing! Hasn't the Author a great stack of photographs which a good illustrator could make into cheaply-reproduced, satisfactory line-drawings? Third and last, we note that the jacket flap of the book says "Mr. Loveridge frequently contributes articles to scientific periodicals and magazines devoted to out-door life." He does. What we hope is, that he will contribute to the public store of good books a thick volume every now and then, in the same tenor as the one over which we are now rejoicing.

A glance at the copious and satisfactory index will indicate the scope of the subjects touched upon, which include not only items from the field of biology, but also those from the field of African sociology.

The type is Linotype Baskerville, set on the page just closely enough to make it very easy to read. But oh, Mr. Loveridge and Harper and Brothers, your book is much too short!

The Author, born in Penarth, Glamorganshire, South Wales, is a University of South Wales man, and has occupied the posts of Curator of Natural History in the Museum in Nairobi, Kenya Colony, and Assistant Game Warden of Tanganyika Territory, East Africa. Since 1924 he has been Curator of Reptiles and Amphibians in the Museum of Comparative Zoology, Harvard University. During World War I he enlisted in the East African Mounted Rifles "because it sounded easier than walking." This little straw will indicate which way the wind blows with respect to many delightful touches in the book. Mr. Loveridge, known and respected as a long-headed scientist, is not at all of the long-faced species.—LEON AUGUSTUS HAUSMAN.

COMMENTS AND CRITICISMS

The Gracious Touch

We are obliged to Mr. James Paul Stoakes of Huntington, W. Va., for letting us know, through the medium of a letter to THE SCIENTIFIC MONTHLY, about Don Gulermo Bonitto. . . . Altogether Don Guilermo strikes us as the perfect weatherman, and if we had him, or someone like him, to do our forecasting in Washington, it would make even this climate almost tolerable.—From an editorial in *The Washington Post,* August 15, 1944.

But something *has* been done about the weather in Washington. See "Moonlight and Roses," *The Readers' Digest,* October, 1944.—EDS.

Philosophy and the Supernatural

The simultaneous publication of Carlson's article "Science and the Supernatural" and Bergmann's "An Empiricist's System of the Sciences" in the August '44 issue was thought provoking.

While Carlson's excellent article rejects irrefutably the supernatural as a means of knowledge, this rejection does not appear to me to have exhausted the subject. Any phase of human behavior and its motivation deserves the attention of science as a phenomenon of human nature. Why then should we ignore, by rejection, the supernatural? This is a source of human motivation so strong that it perseveres in spite of science, and indeed as Carlson points out, in opposition to it. I do not mean to imply that science shall continue to apply its method to alleged manifestations of the supernatural; for this can lead back only to Carlson's position. I suggest, rather, that by the application of historical and psychological data (for lack of as yet unobtainable mathematical data), the scientist may qualify the supernatural with reference to the other phenomena of human behavior.

It would require very little investigation along this line to reveal that the supernatural is but a vaporous screen concealing behind it the phenomena of philosophy and religion. Now there can be no difficulty in relating religion with the supernatural for the very obvious reason that all religious tenets are premised on the supernatural. But what possible relationship could be found to exist between philosophy and the supernatural? Philosophy has often paid tribute to science. Was it not indeed the parent of science? However that may be, I may certainly be allowed to declare that all three, religion, philosophy and science are rooted commonly in man's earliest efforts at orientation. Furthermore, it is a more or less unchallenged truism that with the passage of centuries, each of these has gone its separate way. While granting the truth of this for science, I should like to contend that it is not true for religion and philosophy. Specifically, the contention is that philosophy is still tainted with a fundamentally religious concept.

Consider, for example, Bergmann's application of empiricism to a system of science. (It may be granted, I think, that empiricism, for the scientific mind, is the most acceptable brand of philosophic thought.) Beginning from the position of "common sense," Bergman states ". . . With respect to the physical sciences the problem now stands as follows: How can our narrow criterion, according to which all the scientist verifies are simple statements about the positions of pointers and the shapes of instruments, be reconciled with the obvious fact that physicists very confidently and successfully use such abstract things as 'electrical field' and 'elasticity coefficient' and such theoretical conceptions as 'atom' . . . which nobody ever expects to see or touch like physical things . . . ."

This statement, from the philosophical viewpoint, poses a perfectly valid epistemological problem. Yet to a scientist unfamiliar with the dignity bestowed upon it by age, this question must appear naive, if not obstructive. The scientist, unless he consults the works of scientific psychologists, will restate the question for himself thus: How can I know about anything that I cannot reach directly with my five senses? He will reply immediately with the declaration that because he *does* know about things outside the reach of his senses, he *can* know about them. Furthermore, he will assume the existence of an organic relationship between his senses and his thought processes and will set about finding proof for his assumption. In doing so, he will be well within the precincts permitted by the discipline of science.

Now, when a question is asked, it is because a questionable situation exists to ask about. What, then, is the questionable situation existing in the physical sciences which prompted Bergmann's question? Clearly there is none, since the abstracts used by the scientists are used "confidently and successfully." For lack of any other reason, it may be assumed that Bergmann's question is rhetorical and was posed only for the purpose of breaking down the methodological structure of science the better to study its components. From this process, the concept of "operationism" is seen to emerge. By this, it is understood, that in the formulation of any scientific law, the scientist must have observed in operation every component of the phenomenon, regardless of the degree of divergence of its manifestations. Stated simply, and reduced to its essence, this means that the components of a phenomenon must be given their validity via the senses before they can be

formulated into scientific law. Bergmann is now back at his starting point.

But if he is to maintain his philosophic position, Bergmann cannot stop at this point. He must ask again the same question, this time with reference to operationism. He must again create and, if possible, resolve the cleavage between sensory observations of operations and the thought processes they engender. Once stated along this line, the consistent philosopher has no choice but to continue ad infinitum.

This last is true for Bergmann and his contemporaries in philosophy because they are modern philosophers under the influence of modern science and are, therefore, too sophisticated to resort to the tricks or expedients of their ancient predecessors. These, untroubled by modern psychological science, happily resolved this dualism by submerging its parts into a single whole, naming the parts as attributes of the whole. Despite the fact that this whole has been variously named throughout the history of philosophy, the dualism which it embraces, remains the same. What else can this be but the ancient dualism of body and soul? That it is still a living premise for philosophy today is evidenced by the fact that epistomological problems have not yet given way to the science of psychology.

It is on the basis of this persisting dualism that philosophy may be charged today with addiction to the supernatural. For inherent in this dualism is the concept that thought, or consciousness generally, is a thing apart from the material world. Lacking a world created by scientific investigation, what remains is but a world of the imagination.

To be sure, it is hardly conceivable that Bergmann and his fellow empiricists are consciously searching in the realms of the supernatural for an answer to their problems in epistomology. Yet as long as philosophy continues to pose these problems, it must continue to stand accused, at least, of refusing the answers of science, and by corollary, to be searching for them elsewhere.

It occurs to me, furthermore, that this dualism is the source of a basic contradiction between philosophy and science; a contradiction which must make of the philosophy of science mere sterile speculation. For the moment the means of knowledge employed by science are opened, by philosophy, to question, the validity of science is at once shaken. If, on the one hand, the answers of philosophy are affirmative, science is again valid and the philosopher must in all conscience abandon his position for that of the scientist's. If, on the other hand, the scientific means of knowledge are negated, philosophy collapses together with science into an emphemeral world of mystery, or its by-product, the supernatural.

The great role played by philosophy in the launching of scientific investigation cannot be denied. I feel, however, that philosophy has outlived its usefulness to man's efforts at orientation. More, there is good evidence to believe that philosophy, particularly that of the Germans, is being used for evil ends. Let it then be retired with its greatness and dignity unmarred: Or better, let it be the object of study as a manifestation of man's behavior. Within this "frame of reference," it may still yield much in terms of man's self-understanding.—ANNA ROSENBERG.

The Older Worker

I like the conclusions you [A. J. Carlson] drew in the article on "The Older Worker." Since March, 1942, I have been doing some work for The National War Labor Board, and I have become keenly interested in labor problems as the result of my contacts with labor and industrial management. Since my return from the West Indies, I have had an opportunity to try out your conclusions on one labor organization—a local of the Industrial Union of Marine and Shipbuilders Workers of America. The officers of the Union with whom I talked pointed out the difficulty of inducing older employees to accept a reduction in pay when their utility was impaired by age, but they granted the psychological soundness of the proposal. They reminded me, however, that serious thought might have to be given to the younger worker; and that Social Security was designed to take the old worker out of circulation so as to provide a place for the youngsters. Apparently they anticipate the continuing problem of unemployment.

Among my extra-curricular activities is the management of a hosiery company whose workers belong to the American Federation of Hosiery Workers. This organization makes provision for reduced salaries for the older workers, and we actually have in one of our mills two women who are receiving less than the minimum wage for the job performed, though more than would compensate them for the work which they perform. We apply the privilege of placing people in the group of sub-standard workers very cautiously, and thus far we have received Union endorsement and backing whenever we have taken this step. It is the humane and sensible thing to do.

I have written you these facts because I thought you would be interested to know that at least one of your readers has been interested enough in the application of your conclusions to test them out in a practical way. Too often scientific results are not given immediate application, and their author may not learn the reception which his ideas receive.—HOWARD A. MEYERHOFF.

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DECEMBER, 1944

WARTIME IMPORTANCE OF TROPICAL DISEASES

By BRIGADIER GENERAL JAMES STEVENS SIMMONS

War has focused the spotlight of interest on many diseases which previously were little known and seldom thought of in this country. Until recently the American public derived its limited knowledge of tropical diseases largely from vague descriptions of their imaginary horrors brought back by world travelers and foreign missionaries. People are now keenly interested in these exotic diseases because their fathers, brothers, and sons are fighting in the pest-ridden tropical countries of all the continents of the world (Fig. 1). They want to know more about these diseases and what the Army is doing to prevent them. They also wonder whether certain of these infections may be brought home with the troops and constitute a menace to the health of their communities. These three questions are important to all of us. I shall therefore indicate briefly the

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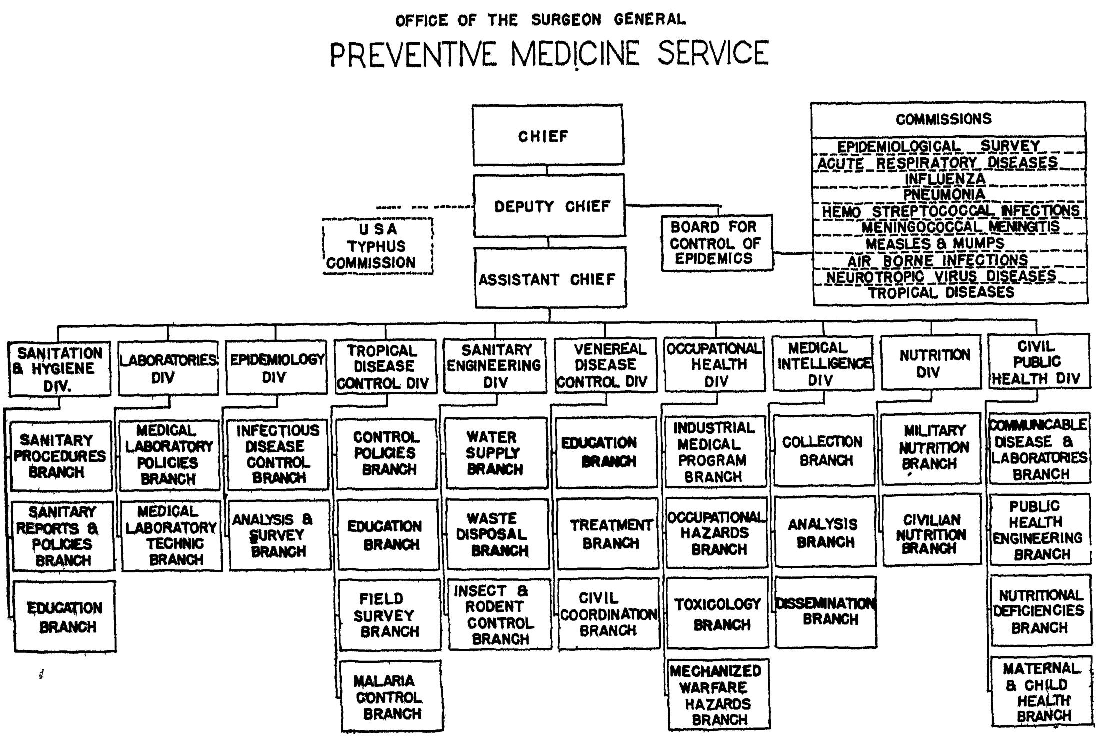
FIG. 1. COMBAT IN THE TROPICS, MAKIN ISLAND

military importance of the various tropical diseases encountered by our Army, consider the program which has been developed for their control, and, finally, present an estimate of their probable significance to the public health of the nation after the war.

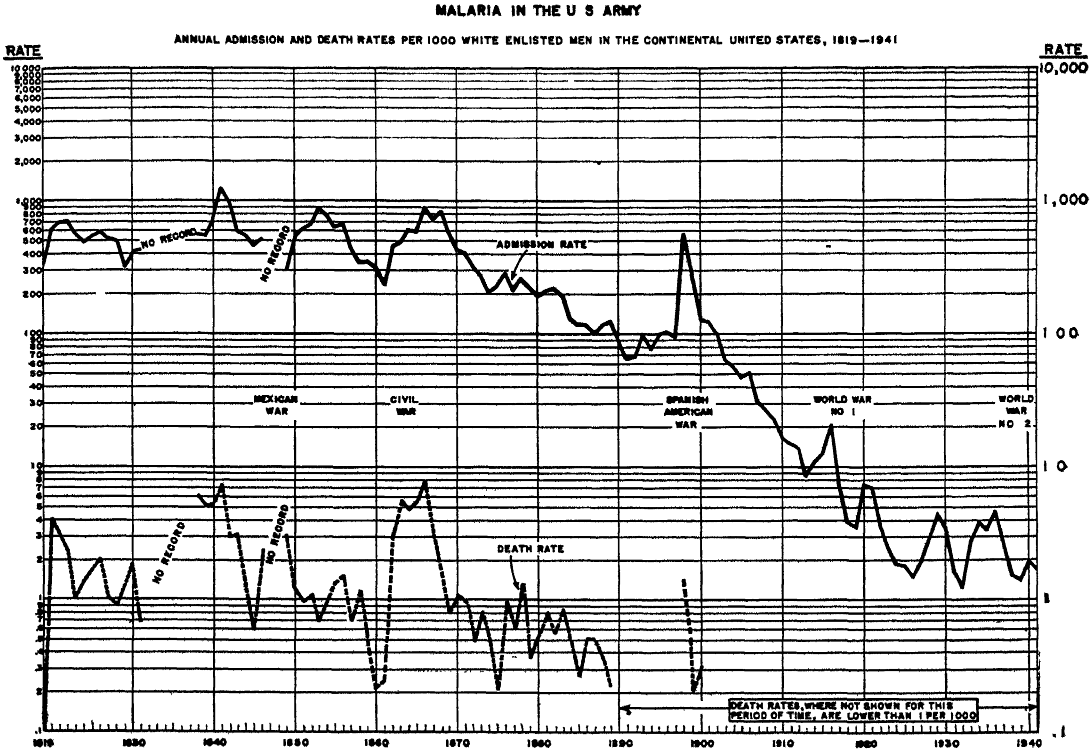
First of all I should like to point out that while tropical diseases have never received the attention of the American public that they do today, these diseases have long been of intense interest to the United States Army. Malaria has been a military problem since the Revolutionary War. After the Spanish-American War the establishment of our outposts in the Philippines, Panama, and Puerto Rico presented the Army with new problems in the control of tropical diseases and new opportunities for their investigation. Thus for a long time the prevention of such diseases among troops has been a matter not only of interest, but of concern, to the Medical Department of the Army.

When it became apparent in 1940 that this country might be drawn into the present world conflict, The Surgeon General began to organize and prepare the Medical Department to meet any situation that might arise. The Preventive Medicine Service (Fig. 2) was established and expanded in his office. This Service includes a Tropical Disease Control Division, which co-ordinates all the Army activities for the prevention of such diseases. The control program has been built up with the assistance of the Commission on Tropical Diseases of the Board for the Control of Epidemics in the Army, which is composed of civilian consultants to the Secretary of War. Serving on this Commission are some of the country's leading experts in tropical medicine. A Subcommittee on Tropical Diseases, formed by the National Research Council at the request of The Surgeon General, has also helped to advise the Army concerning the treatment and prevention of such infections. Later, under the auspices of the Committee on Medical Research, Office of Scientific Research and Development, a comprehensive investigative program dealing with tropical diseases was undertaken for the armed forces with the advice of the National Research Council.



U. S. Army Medical Museum Negative No. 81089

FIG. 2. ORGANIZATION OF THE PREVENTIVE MEDICINE SERVICE



U. S. Army Medical Museum Negative No. 78243

FIG. 3. MALARIA IN THE U. S. ARMY, 1819–1941

Many institutions and agencies are now making both laboratory and field studies, and many thousands of dollars are being spent monthly in the search for more effective drugs, insecticides, and repellents with which to combat exotic diseases. Through this comprehensive wartime research program great progress has already been made in tropical disease prevention.

As the Army expanded to wartime strength, there was a concurrent expansion of the Medical Department. Four years ago the peacetime Regular Army Medical Department consisted of only about 1,000 officers of the Medical Corps and a few hundred additional members of the Dental, Veterinary, and Medical Administrative Corps. At present it includes over 40,000 Medical Corps officers alone, and its total strength is more than 100,000. In addition there are several hundred thousand Medical Department enlisted men. In fact, the present Medical Department is larger than the total Regular Army before this war. Doctors, sanitary engineers, and technicians, skilled in every phase of preventive medicine and public health, have been brought in from civil life. Most of these experts were unfamiliar with the problems of health maintenance peculiar to tropical regions. Special training was therefore provided for these men after they came in the Service in order to orient them in this new speciality before going into the field, for never before has the United States Army conducted such large-scale military operations in the tropics. It is much more difficult to protect troops from disease during battle than to prevent the same diseases among soldiers living at well-established posts where sanitary conditions can be carefully controlled and hygienic standards of living enforced. Therefore the experience of this war is a real test of the effectiveness of the Army's preventive medicine program.

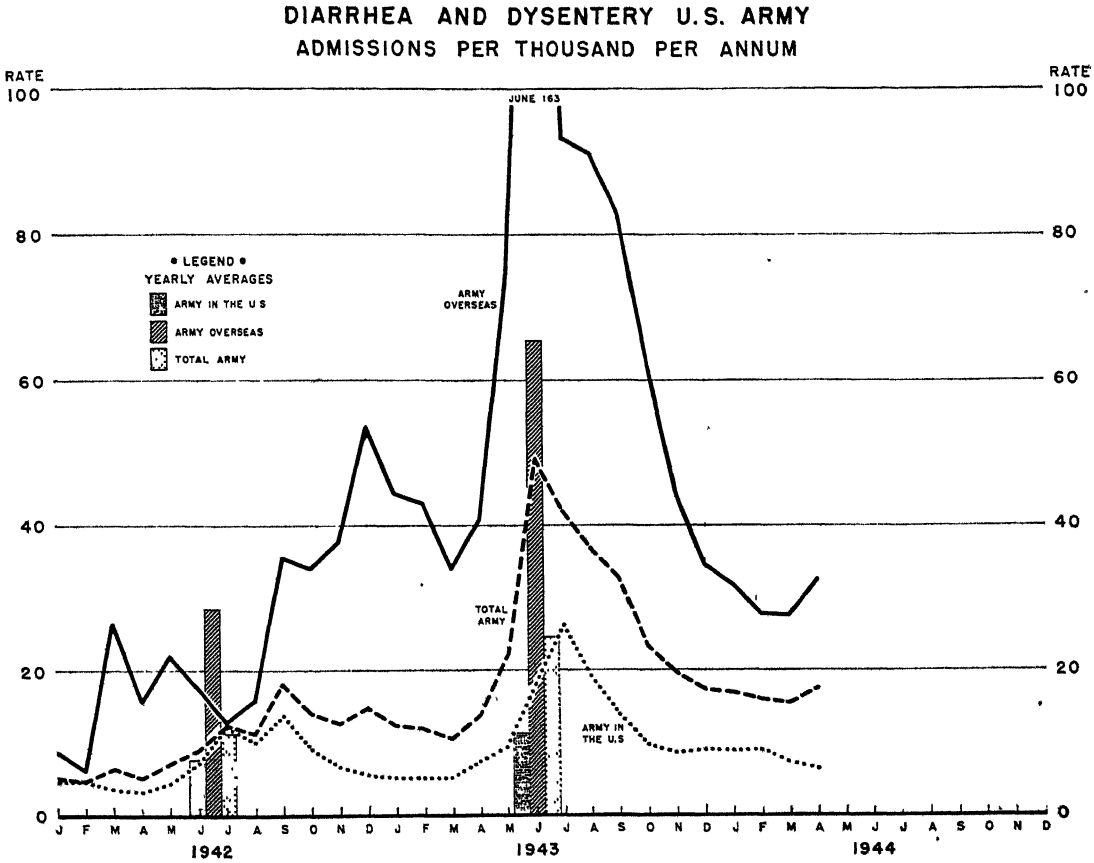
For more than two years American forces have been operating extensively in tropical areas. From this experience it is possible to evaluate the military importance of the various exotic diseases to which our troops

have been exposed. Many infections which have long been notorious as scourges of native populations in various parts of the world have been of little or no importance to our forces. For example, African sleeping sickness, long recognized as a fearful handicap to the natives of certain parts of Africa, has not been reported among the officers and soldiers who established and operate the Air Transport route across the endemic area of this disease. Schistosomiasis, which is widespread among the natives of many regions, has been acquired by only a few of our troops based in such endemic areas as Puerto Rico, Egypt, and North Africa. Other well-known tropical infections, including leishmaniasis, onchocerciasis, yaws, leprosy, yellow fever, plague, and cholera, have either failed to occur or their incidence has been so low that it has not affected the health record of our Army.

A few tropical diseases, however, have been of distinct military significance, not because of their mortality, but because of the incapacity and the loss of time which they have caused. Malaria has been the number one hazard, and the dysenteries have also been an important cause of noneffectiveness. Dengue fever, sandfly fever, filariasis, and scrub typhus have at times caused concern in certain areas. All of these infections are either transmitted by insects or, as in the case of dysentery, insects play a significant role in their spread. Effective vaccines are not available for any of them. For this reason, the development of new and more effective insecticides and insect repellents has constituted one of the most important parts of the Army's preventive medicine program. Through the assistance rendered by the research agencies of the nation, we are now armed with a number of effective new weapons. These include potent insect repellents, the freon-pyrethrum aerosol

Signal Corps Photo

FIG 4. MOSQUITO CONTROL ON GUADALCANAL



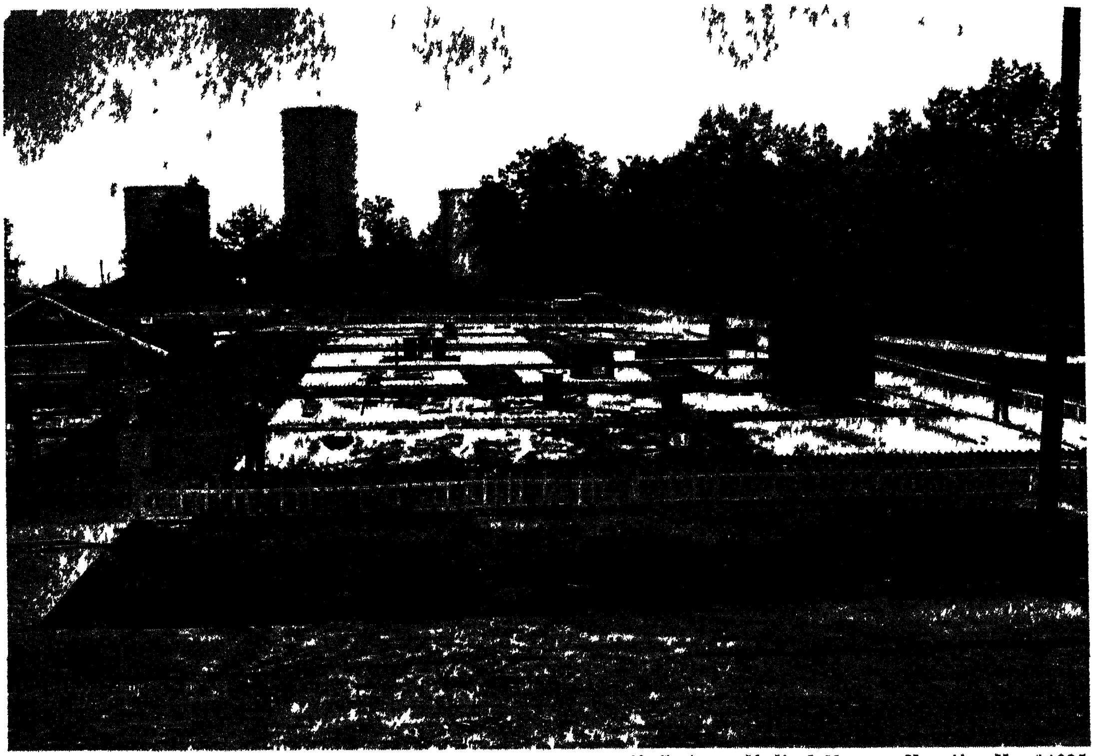
U. S Army Medical Museum Negative No. 81742

FIG. 5. DIARRHEA AND DYSENTERY IN THE U. S. ARMY

bomb, methyl bromide for delousing clothing, and, finally, the greatest of all, DDT, for use both in the control of lice and mosquitoes. The basic research and development for military purposes of the four items just mentioned was done by the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. The discovery and the field application of DDT to the control of insect-borne diseases, will, in my opinion, prove to be the outstanding medical advance made during this war. It will exceed even penicillin in its ultimate usefulness in the preservation of health and the saving of human lives.

Malaria has always been the enemy of armies fighting in hot and warm climates, and ours is no exception (Fig. 3). In this country the Army has carried on an enormous antimosquito campaign since 1941. This has been supplemented by the equally extensive extramilitary mosquito campaign of the Public Health Service. Together they have reduced malaria among the troops at home to the lowest point ever reached. In certain tropical theaters, however, the malaria casualties have been an important factor in military operations. In some of the early campaigns, the malaria rates were high. Because of military situations men fought in hyperendemic regions without adequate antimalarial supplies and without benefit of mosquito control (Fig. 4). Great improvement was made in later campaigns. The incidence rates in the most highly malarious theaters are now less than one-fourth of what they were early in the war. On the whole the Army has had a good record in preventing malaria, and the death rate has been negligible.

The dysenteries are a constant menace to armies in the field. Their control is much



U S Army Medical Museum Negative No 81685

FIG. 6. SANITARY DEMONSTRATION AREA AT FT. DEVENS, MASS.

more difficult in tropical countries where standards of sanitation are primitive and troops are more exposed to both the bacillary and amoebic forms of the disease. The incidence rates for the diarrheas and the dysenteries have at times been a matter of concern (Fig. 5). There have been no great epidemics, however, and the total prevalence has been less than in other armies during this and past wars. Our troops are provided with every possible sanitary safeguard (Fig. 6) to protect them against intestinal diseases.

At fixed installations all Army water supplies meet modern sanitary standards Proper garbage and waste disposal, together with screening and the use of insecticides, keep down the potential menace of flies. During field operations the problem of dysentery prevention is more difficult and, like the control of malaria, depends more directly upon the individual soldier. Thorough training in sanitation is given to everyone in the Army, and, in general, high standards prevail. Captured Japanese camps offer a shocking comparison with the excellent sanitation maintained by our own troops

The Rickettsial infection known as *scrub typhus* has been of considerable military importance in the Pacific and Asiatic theaters. It is transmitted by larval mites which infest the long Kunai grass (Fig. 7) of New Guinea and the jungle undergrowth of other Far Eastern regions Unfortunately, we do not have an effective vaccine. The number of troops acquiring scrub typhus has not been large, but the disease causes concern out of proportion to its prevalence because of the mortality rate, which has ranged from 3 to 10 per cent.

Last year The Surgeon General sent to New Guinea a Commission, formed under the auspices of the Army Board for the Control of Epidemics and the U. S. A. Typhus Commission, to investigate scrub typhus and recommend preventive measures. Fortunately the repellents used to control malaria are also effective in protecting soldiers against the mite vectors of scrub typhus,

especially when they are applied to the clothing. Scrub typhus will remain a problem as our forces continue their advance to the Asiatic mainland.

Filariasis has long been a notorious example of the terrifying infections to be found in tropical countries. The monstrous deformities of the legs (Fig. 8) and other parts of the body, depicted in textbooks for tropical medicine, have created a feeling of disgust and horror in the minds of most readers. As a rule the disease occurs only among the natives of the endemic areas. However, under conditions of war, considerable numbers of men stationed in the South Pacific Islands have acquired the infection and have manifested early symptoms. Such men have been returned to this country to avoid exposure to further infection. Continued reinfection over a long period of years is apparently necessary to produce deformities grave enough to warrant the term 'elephantiasis.' Although it has been a source of annoyance and of some mental anxiety to the men infected, filariasis has not been a problem of real military significance in the Army. It will probably be of no real importance in this country, and its spread is not anticipated.

Dengue fever and *sandfly fever* are nonfatal, disagreeable diseases of short duration. They may, however, assume considerable military importance when large numbers of susceptible troops are exposed to infection for the first time. Under such circumstances both diseases tend to appear in explosive epidemics, thus incapacitating large numbers of men within a short time. Dengue has occurred most frequently in our forces in the Pacific, while sandfly fever has been most common in the North African and Middle East Theaters. During the Sicilian Campaign cases of sandfly fever were numerous, and in some instances the disease was confused with malaria. The method of choice for their prevention is control of the respective insect vectors. The new insecticides and repellents developed to combat

Signal Corps Photo

FIG. 7. SCRUB TYPHUS CONTROL ON GOODENOUGH ISLAND

*Courtesy of Colonel Richard Strong**

FIG. 8. ELEPHANTIASIS OF THE LEGS

malaria can be successfully employed against the Aedes mosquito vectors of dengue and the Phlebotomus vectors of sandfly fever.

The intestinal parasites, especially hookworm, are common in tropical countries. Many of our soldiers are exposed to infection with the latter as they crawl through the jungle (Fig. 9) or dive into air raid shelters or trenches previously contaminated by natives. It is known that a considerable proportion of some units in the Pacific have acquired uncinariasis, but as a rule the infections have not been severe enough to cause noneffectiveness. It may be expected, however, that many of the men who have served in the tropics will come back with intestinal parasitic infections, both helminths and protozoa. Therefore, careful stool examinations should be made a routine procedure when such individuals apply for medical care.

* Reproduced by permission of the Blakiston Co. from Stitt & Strong . . . *Tropical Diseases*, 6th ed.

The question as to the possible spread of tropical diseases in the United States by troops returning from overseas has captured the imagination of the entire country. For more than a year it has been a subject of wide discussion by the medical profession, lay officials, and the general public. Undoubtedly such diseases will be introduced from abroad, but on the whole I believe that the future dangers have been overemphasized. Only a few of the many tropical diseases have been of appreciable importance in the Army. The majority of such diseases have either failed to occur among our troops, or their incidence has been so low that the possibility of their introduction into the United States by returning soldiers cannot be considered as a public health problem. It is true that new foci of malaria and perhaps other infections may be established. However, by maintaining the present preventive safeguards and by taking prompt preventive action, it should be possible to control such potential outbreaks quickly and effectively. The high standards of personal hygiene, sanitation, and preventive medicine that exist in the United States are believed to offer good safeguards against serious consequences from the introduction of exotic diseases. The Medical Departments of the Army, Navy, and Public Health Service are fully aware of this problem and are prepared to deal with any trouble that may arise.

The most important task connected with the return of such infected personnel is to insure prompt diagnosis and proper treatment of symptoms which may occur after the troops have returned to civil life. This means that every physician in this country should be able to recognize and treat tropical diseases. This in turn indicates the need for what has already been started; namely, the development of more adequate training in tropical medicine in all of our medical schools.

The importance and interest in tropical diseases which have developed during this war will not decrease with the cessation of

Signal Corps Photo

FIG. 9. JUNGLE FIGHTING ON BOUGAINVILLE, FEBRUARY, 1944

hostilities. Undoubtedly we shall maintain bases in many faraway places, including locations in the tropics. Our troops stationed overseas will continue to require an intelligent application of the knowledge that has been gained in the prevention of tropical diseases. The volume of travel between this country and the tropical regions of the world will increase. The speed of travel by modern aircraft will increase the chance of introducing tropical diseases and disease vectors. The future health program of the country will be more closely knit with international health. The hazards of tropical diseases will become more world-wide, but these hazards can be met and neutralized if we continue to develop the knowledge and the health facilities now available for that purpose.

RECLAIMING STRIPPED LANDS IN ILLINOIS

By LESLIE A. HOLMES

It is indeed unfortunate that the term 'spoil bank' or 'strip mine dump' became associated with the strip mining industry. Both 'spoil' and 'dump' mean something undesirable, to say the least, to the average American; so upon hearing the words 'spoil bank' one visualizes an area of ground torn up by man and piled into unsightly dumps, yet the average person going to Yellowstone Park will spend additional money to see the Bad Lands, a rugged area of 25,000,000 acres developed by nature. We tend to see the good side of the Bad Lands, but the bad side of strip mine hills.

Illinois is the leading producer of coal mined by stripping and has one of the largest acreages of spoil banks in any state (Fig. 1). In 1941, 23,981 acres had already been mined. At that time it was conservatively estimated that the state contained an additional 34,840 acres of shallow coal adaptable to recovery only by the strip mining method. This means that approximately 0.16 per cent of the area of the state may eventually be stripped of its coal. Of this area, 27,932 acres are classed by the Soil Survey Division of the University of Illinois as not adapted to general farming (Fig. 2). This is almost one-half of all the mined or mineable acreage.

Forestation. Because it was recognized that strip mining was taking land off the tax

FIG. 1. A LAKE IN THE LAST CUT OF A STRIP MINE NEAR WILMINGTON,
FORMED SINCE MINING BY THE NORTHERN ILLINOIS COAL CO. CEASED IN 1929. THE LAKE, FROM THIRTY TO FORTY FEET DEEP IN SOME PLACES, WAS STOCKED WITH GAME FISH. THE TREES WERE SEEDED BY NATURE.

FIG. 2. TYPICAL APPEARANCE OF LAND TO BE STRIPPED IN SOUTHERN ILLINOIS
THE SOIL IN THIS AREA IS THIN AND BADLY ERODED IN MANY PLACES. THE TREES IN THE FOREGROUND ARE THORNY LOCUST AND ELM. THIS LAND IS THE PROPERTY OF THE SOUTHWESTERN ILLINOIS COAL CORP., PERRY.

list and making it unsightly as well, some of the strip mining companies as early as 1930 began experiments designed to reclaim their stripped land for productive use. During that year 42,000 trees were planted. From 1938 through 1943, 8,337,400 trees have been planted at a cost to the mining companies of $95,637.

When forestation was started nothing was known as to the types of trees that would grow on the dumps, how close to plant them, or what to expect as a survival ratio. For that reason twenty species of trees were commonly planted. The survival ratio proved to be exceedingly high for each species, with the exception of the Osage-orange which had a survival of only 10 per cent. As a result, only 69,500 of the latter have been planted thus far, whereas 2,407,900 black locust trees, with a survival of 92 per cent, have been planted. In addition, 1,804,500 short leaf pine trees, with a survival of 77 per cent, were also planted (Figs. 3 and 4). Almost all of these plantings were on spoil piles as they were left by the machines and without previous fertilizing or cultivation. In fact only a spade of earth was loosened and the young tree set in.

It is estimated that 8,466 acres have been forested up to the end of 1943. This acreage is about one-third of the land stripped. All the trees were about one year old when they were purchased from the state nurseries, and the cost of planting stock and labor has averaged $11.00 per acre for the state as a whole.

Financial Returns. One of the major surprises in planting seedlings on strip mine dumps was the fact that in many cases the trees grew faster than those on undisturbed land. On the mine dumps at the Midland Electric Coal Corporation near Atkinson,

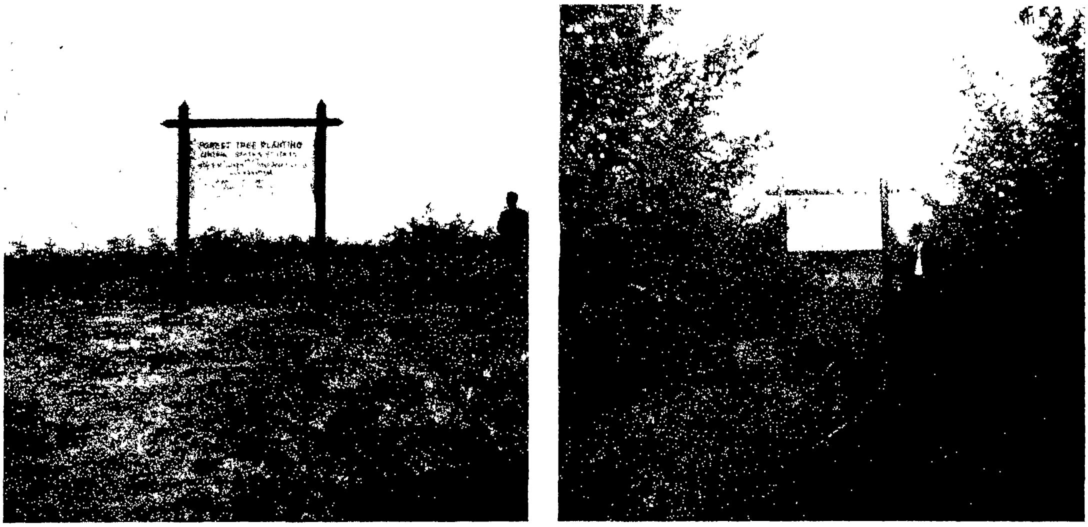


FIG. 3. BLACK LOCUST PLANTINGS ON PARTIALLY LEVELED SPOIL BANKS
Left, THE TREES WERE ONE YEAR OLD WHEN PLANTED. THE PICTURE WAS TAKEN SIX MONTHS AFTER PLANTING. *Right*, THE SAME TREES AFTER ANOTHER YEAR OF GROWTH—CENTRAL STATE COLLIERIES, INC., ST. DAVID, ILL.

Illinois, black locust grew to be about twelve feet high in three years, while those planted on undisturbed land nearby grew to be only about six feet tall in the same three years (Fig. 5). It is probable that the undisturbed soil had lost much of its fertility, whereas the soil on the mine dumps was new and unleached, thus accounting for the exceptional growth of trees on the dumps. One of the Illinois state foresters writes, "... generally speaking trees will grow almost as well on strip mine land as on other soil and in many cases will do better. . . ."

Under normal conditions the sale of lumber and posts over a 40-year period will average $3.71 per acre a year. This figure is based on extremely conservative estimates of $5.00 per 1,000 board feet and $0.10 each for posts. A more recent development in the wood utilization industry is the use of wood

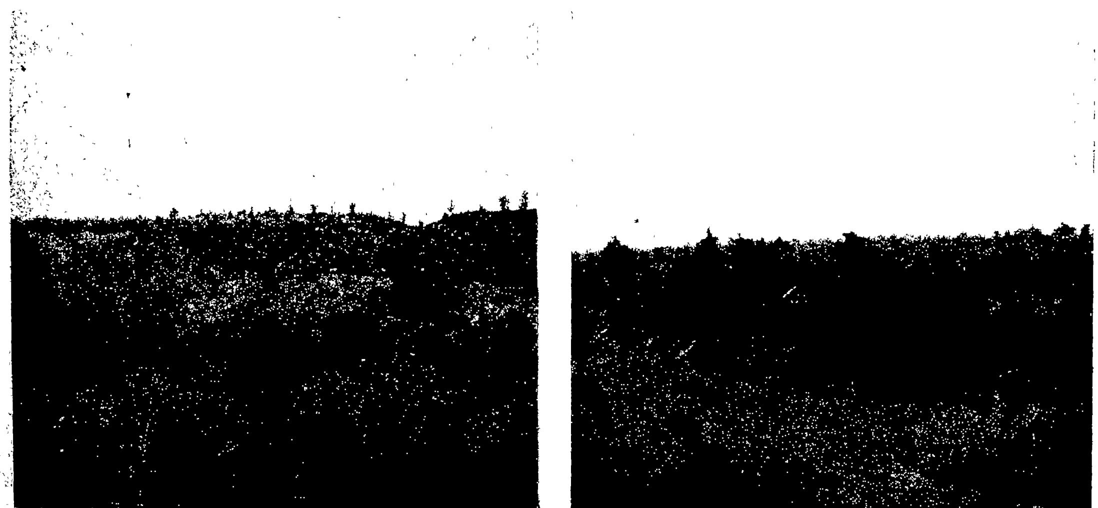


FIG. 4. SHORT LEAF PINE PLANTED ON SPOIL BANKS
Left, A TWO-YEAR GROWTH OF TREES ON THE PROPERTY OF THE PYRAMID COAL CORP., PINCKNEYVILLE, ILLINOIS. *Right*, TREES PLANTED FOR FIVE AND ONE-HALF YEARS—TRUAX-TRAER COAL COMPANY, ELKVILLE, ILLINOIS.

FIG. 5. BLACK LOCUST PLANTINGS
Left, THESE TREES SHOW THREE YEARS OF GROWTH AFTER PLANTING IN UNDISTURBED SOIL NEAR ATKINSON. *Right,* TREES OF SAME AGE BUT GROWING ON SPOIL PILES, MIDLAND ELECTRIC COAL CORP., NEAR ATKINSON.

chips which will probably be sold by the ton. In this manner slabs, trimmings, and stumps will be as marketable as the trunk. Cottonwood trees are particularly well adapted to this processing, and more trees of this type are to be planted in the near future. Evergreen trees may be used after five or six years for Christmas trees, and posts may be obtained from locust plantings in ten to fifteen years. With a proper rotation of tree crops, the per acre value of wood can be stabilized at perhaps $5.00 rather than $3.71 previously quoted. Later there is a possibility that valuable lumber and nuts may be produced from the 453,500 black walnut trees already planted and from other nut trees still to be planted. On certain spoil banks favorable results have been obtained by planting orchards, berry patches, and vineyards.

Successful forestation, however, has not as yet been achieved in all the strip mine areas. One of the most difficult districts lies south of Wilmington in northern Illinois. In this location the glacial debris and shale immediately above the coal form a hard, compact mass so nearly impervious to water that it will not support tree growth, except in localized places. Near Morris and Ottawa, also in northern Illinois, successful forestation has thus far been impossible because of the large amount of acid in the spoil banks. Some of the mine dumps in Williamson and Saline counties, of southern Illinois, consist so largely of rock and shale that weathering has not as yet progressed sufficiently to produce soil capable of supporting trees. While the outlook for successful forestation in areas of these types is discouraging, the total acreage that has not responded is probably not over 5 per cent of the amount thus far stripped and does not materially change the general picture of forestation for the entire state.

Pasture. A few miles south of Canton, Mr. Byron Somers decided to experiment with the use of spoil piles for pasture. He bought 800 acres of land, 600 of which was

spoil banks acquired from the Truax-Tracr Coal Company; the remainder was average Fulton County pasture land. He had noticed that naturally seeded weeds and sweet clover grew in abundance on the piles and that large rocks were scarce. Also he had seen that the numerous small lakes remained clear and fresh and that the large lake in the last cut offered an opportunity for fish stocking since it was 2.5 miles long, over 100 feet wide, and at certain places as much as 45 feet deep.

In 1935 he began to seed the sides of the spoil banks. By 1938 the grasses were sufficiently developed for cattle pasture. Since that time beef cattle have been pastured on these lands the year around, except during the coldest winter months. Sweet clover, blue grass, and timothy seem to grow stronger, to be more nourishing, and to remain green longer than on the 200 acres that were not disturbed. The probable explanation, previously mentioned, is that the spoil banks still contain all the original soluble minerals since there has been little opportunity for leaching. Also the ground-water table is higher because the rain falling on the area has no outlet and sinks into the ground or collects in the depressions between the banks. This water, of course, is an important factor in keeping the grasses green over a long period of time. The usual method of planting is to seed the blue grass in the valleys and let it grow up the sides of the spoil banks. Sweet clover is usually planted along the sides and tops. Many of the top ridges are extremely sharp because no leveling has been done in this area, except enough to permit a rough road to be built through the hills.

After having been fed silage and hay during the winter, cattle are turned onto the seeded banks early in the spring. As these cattle enter the pasture they are usually rangy but not particularly thin. With a summer's feeding on the spoil bank range they will gain about 200 to 300 pounds each, and in many cases also produce a calf that will weigh from 150 to 350 pounds by autumn (Fig. 6). In 1942, 250 cattle were pastured, and these together with the calves gave a clear profit of $7,000, or almost $9 an acre. This profit was greater than could be obtained from an adjacent 400 acres of undisturbed farm land planted in the usual manner. In this case the spoil banks represented a profit of from $25 to $35 an animal per year. The rough topography is of no hinderance to the cattle; they graze both on the ridges and in the valleys, and usually

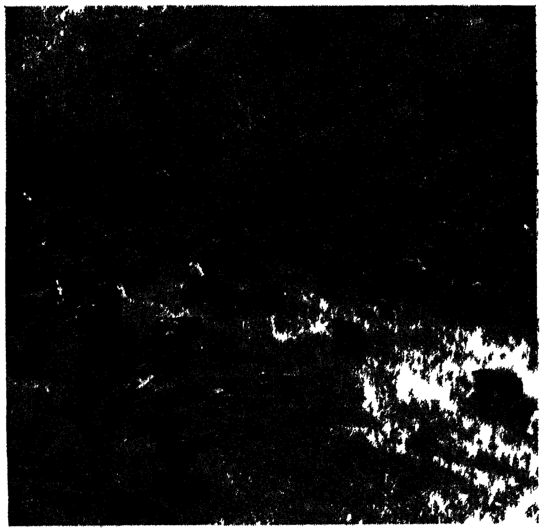


FIG. 6. CATTLE OF MR. BYRON SOMERS, CANTON, ON SPOIL BANK "RANGE"
Left, THESE VIGOROUS ANIMALS FED ALL SUMMER ON GRASSES THAT HAD BEEN SEEDED ON THE MINE DUMP. *Right,* THIS AREA, NATURALLY FORESTED, WAS MINED BY TRUAX-TRAER 12 YEARS BEFORE IT WAS PHOTOGRAPHED.

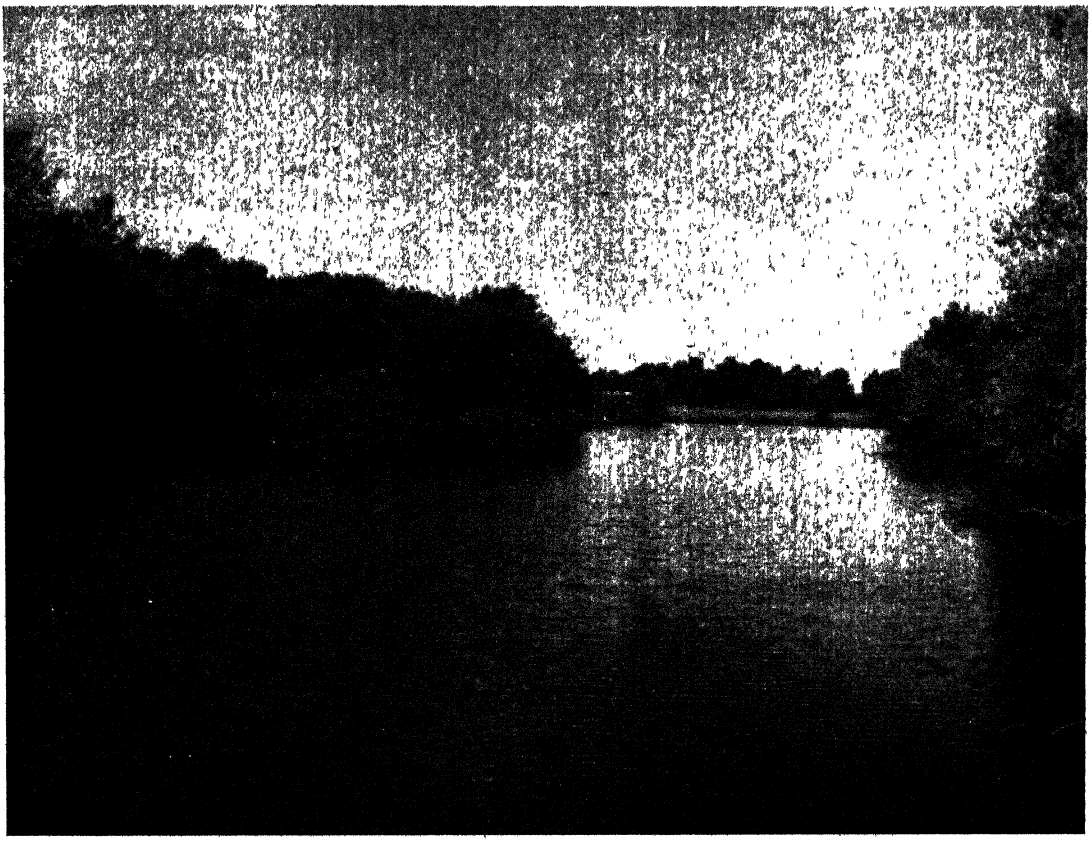


FIG. 7. PUBLIC RECREATIONAL AREA ABOUT A FINAL-CUT LAKE
THIS AREA WAS MINED IN 1928 BY THE MIDLAND ELECTRIC COAL CORPORATION, ATKINSON, ILLINOIS. THE LAKE IS STOCKED WITH GAME FISH, AND THE TREES WERE PLANTED ON THE HILLS BY CONSERVATIONISTS.

rest upon the tops of the ridges where winds reduce fly and mosquito pests to a minimum. It is improbable that similar use of all spoil banks within the state would produce such profits, because some areas, particularly in the southern counties, have much poorer soil and more large rocks and are not as readily adaptable to grazing as those in Fulton County. However, this experiment does show the potential profit to be obtained in certain areas of Illinois, which now has over 2,500 acres of such pasture land. This is about 10 per cent of the area thus far mined.

At its Fiatt mine in Fulton County the Truax-Traer Coal Company is taking the precaution, whenever possible, of piling their mine dumps in such a way that the heavy rocky material and shales are placed on the bottom and the clay and fine soil on top. This company plans in the future to seed all of its spoil banks in this area and eventually to pasture sheep as well as cattle on the "range." Here per acre profits will probably be greater in pasture than in trees. The mining practices followed by this company can be used by many strip mining companies with little added cost to themselves and to a great advantage in their reclamation work.

Recreation. The irregular hills, valleys, and lakes developed by the stripping machines are ideal for recreational purposes (Fig. 7), especially after becoming naturally forested and grassed or, better still, after being artificially forested and grassed. Fishing, boating, and swimming are frequently enjoyed by visitors to these beauty spots. Game fish seem to do particularly well in the large, deep, cool, and clear lakes made by the last cut of the stripper. Mr. Somers reported that from his stocked lakes a bass

weighing almost seven pounds was taken in 1943. Several weighing five pounds were also caught as were numerous smaller ones. Hundreds of trout have been placed in this lake, but angling for these fish has been prohibited by the owner. Will, Henry, and Vermilion Counties are noted for fishing in mined out lake areas. Many strip mine lakes in southern Illinois have also been stocked.

Game of all kinds, particularly fur bearers, are found in abundance in the rough terrain of the spoil banks From the pasture land described above, muskrat pelts valued at $250 and four mink pelts worth $32 were taken and sold in 1943. Trapping has been exceptionally lucrative on all of the Illinois spoil banks. Quail and pheasants are raised and liberated by some of the companies in co-operation with the State Department of Conservation. Two-thirds of the birds are released locally in areas other than mine dumps, and the remaining third are liberated on and near the mine dumps where protection is greater than in the adjacent areas. Wild ducks commonly use the lakes in their migratory flights; and duck hunting in these surroundings has been reported as unusually good. In all, about 12 per cent of the strip mine dumps in Illinois are now in recreational areas.

Conclusion. By turning the spoil banks into forest, pasture, recreational areas, and game preserves, all of them may be used to advantage, and many will return a yearly profit to the owner equally as great as that produced by the land prior to mining. Certainly with a minimum of time and labor the great majority of strip mine dumps in Illinois can become "cover hills "

A SCIENTIST'S PSALM*

Almighty Power! Too vast to be
Compassed by human mind or hand,
With loving awe we reverence Thee,
Striving to see and understand.

Within the atom's ordered maze,
Earth's lumined book, writ to be read,
Beyond the star-dust's far flung haze,
We seek Thy works with joy, not dread.

Our souls, which by Thy richest grace,
Have waked to justice, mercy, love,
Find in humanity Thy face,
And serving men, serve Thee above.

—Jerome Alexander

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STONES FROM TREES*

By CHARLES MILTON

THE spectacle of a tree firmly rooted in apparently barren rock, from which it draws its sustenance, is by no means uncommon. In the economy of nature the strong rock is broken down and partly dissolved, and some of its mineral constituents become part of the tissues of the growing plant. The cycle is a very long one, commencing with the fresh crystalline rock, its incipient weathering (permitting a toe-hold, so to speak, by the seedling), the absorption through the roots of the slowly dissolving rock-substance, its incorporation in the wood and leaves of the growing plant, and, with the death of the plant, the dispersion of the mineral matter into leaf-mold humus, or rain-water solutions, and eventual distribution over the land and into the sea. At no time, it would seem, in human history would this mineral matter ever be reassembled so as to form massive stones or rock; and yet, surprisingly, this may occasionally happen.

In Figure 1 is pictured such a stone, produced from a tree. It is but part of an originally larger piece, a couple of pounds in weight. Such stones have been found in recent years in at least three localities: Grand Canyon of Arizona, northern Idaho, and southern Washington. In all places the mode of occurrence is similar. The stones are found in the hearts of tall trees that have been through forest fires or have been blasted by lightning. The Arizona specimen was found by William J. Kennedy, a forest ranger who noted the burning, lightning-struck tree shown in Figure 2. In his monthly report for September, 1943, he wrote:

> While at a fire on the north side of Kanabownits Canyon one-quarter mile from the Point Sublime road and four and one-half miles from the North Entrance road on September 11 [1943] the writer found several pieces of a peculiar substance which somewhat resembled a kind of lava ash. They came from a tree that had been hit by lightning and had burned for several days before the fire in it had been discovered. The specimens had pieces of charcoal intermingled with the rock. The top of the tree had been blown to bits by lightning and no trace of it could be found. The tree was felled during the process of suppressing the fire and upon measurement it was found to be 49 inches in diameter 30 inches above the ground—it was swell-butted at the ground—and it was 36 inches in diameter at the point where the specimens were found, 54 feet above the ground. The tree was a white fir, *Abies concolor* [and grew at approximately 8500 feet elevation]. Several of the specimens were sent to the South Rim.

The other occurrences were in trees that had rotted at the heart, while still standing, and had later been in forest fires. Essential requirements for the formation of the stones are the accumulation of decayed wood or ash surrounded by sound wood, with vigorous burning of the wood subsequently so as to melt down the enclosed ash.

At this point it may be reasonably queried why we do not find these stones when we burn wood in fireplaces or out-of-doors where hot fires have burned above ash beds? If the process were as simple as that, such stones ought to be quite common, but there is one further essential requirement. The burning of the wood and the melting of the ash must take place with a minimum accession of air (oxygen). In other words, the combustion and fusion must take place under such conditions that the carbon dioxide produced by the burning is in sufficient concentration to support the weight of the overlying air-column. In technical language, the vapor pressure of the carbon dioxide resulting

Natural size

FIG. 1. FUSED WOOD–ASH STONE

IN THIS FRAGMENT OF A SPECIMEN FROM NORTHERN IDAHO NOTE THE CHARCOAL EMBEDDED IN THE STONE.

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from combustion of the wood must approach one atmosphere. The reason for this will be made clear when we study the composition of the stone.

Just as the biologist prepares from his specimens, animal or vegetable, slices or sections of extreme thinness to permit light to pass freely through them, so does the student of stones and rocks make use of thin sections of his materials, a thousandth of an inch, or even less, in thickness. Light passes freely through such thin slices of rock, and most rocks when viewed in such slices under the microscope are as beautifully transparent as a stained-glass window. Of course, the mineralogist cannot use the biologist's steel microtome on hard rocks, but he achieves his end by a process of grinding. In a matter of minutes skilled technicians can prepare from a granite or marble or basalt a continuous unbroken slice inches across and as thin as tissue. Such thin sections may be prepared from our tree stones, and the typical aspect of such, as seen under the microscope, is shown in Figure 3.

It is seen that the stones consist largely of platy crystals which resemble rods or laths in cross section. Chemical analysis of the stones further shows that these crystals are a double carbonate of potassium and calcium ($K_2CO_3 \cdot CaCO_3$). Except for its occurrence in these stones, this compound is unknown as a naturally occurring mineral. It has, however, been produced artificially in the laboratory, and its properties determined by several investigators. As the compound is heated it loses carbon dioxide at an increasing rate until at 813° C. it cannot exist but breaks up into potassium carbonate, lime, and carbon dioxide. However, if the heating takes place in an atmosphere of carbon dioxide, just as many molecules of this gas enter the crystal as leave it, and the substance is then stable.

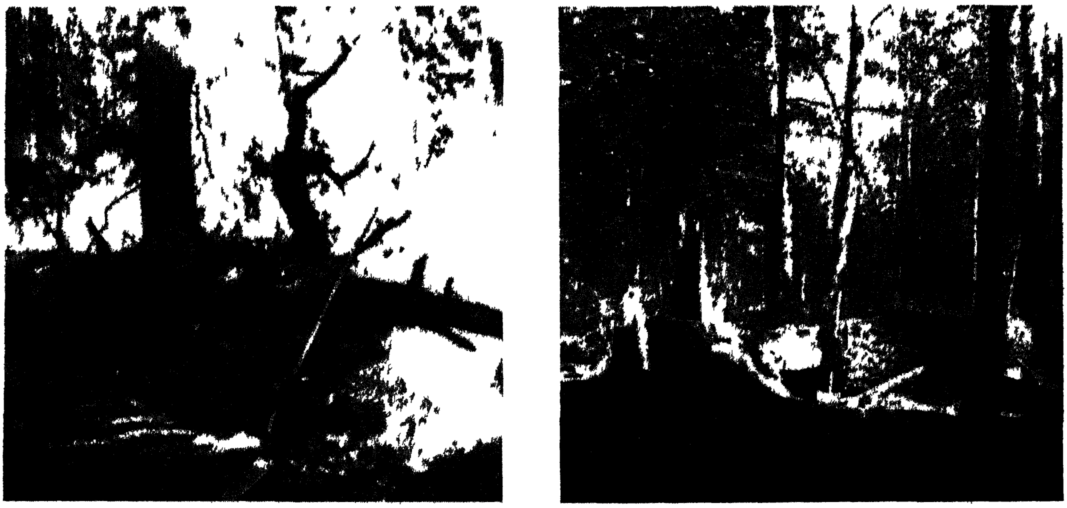


FIG. 2. A LIGHTNING–STRUCK WHITE FIR TREE, GRAND CANYON, ARIZONA
Left, SHATTERED TOP OF BURNING TREE; *right,* ITS STUMP AND TRUNK, AFTER IT WAS FELLED TO SUPPRESS THE FIRE. THIS TREE WAS THE SOURCE OF WOOD-ASH STONES FOUND BY PARK RANGER, WILLIAM J. KENNEDY.

Our grandmothers had more concern with wood ashes than we have: The family soap supply was often made at home from wood ashes, or pot-ash. The ash consisted of potassium and calcium carbonates; by leaching, the soluble potash lye (or leach) was saved, and the insoluble limy residue was discarded. These ashes, however, were obtained by free burning with plenty of air, and in all probability no formation of ash-stones ever occurred; at least, none has been recorded.

But if the ash is melted while enveloped in carbon dioxide from the surrounding burning wood, a condition that obtains when the burning occurs within a standing stump, the ash will fuse together to form our stones. Usually, though, the burning takes place under conditions that cause the dispersion

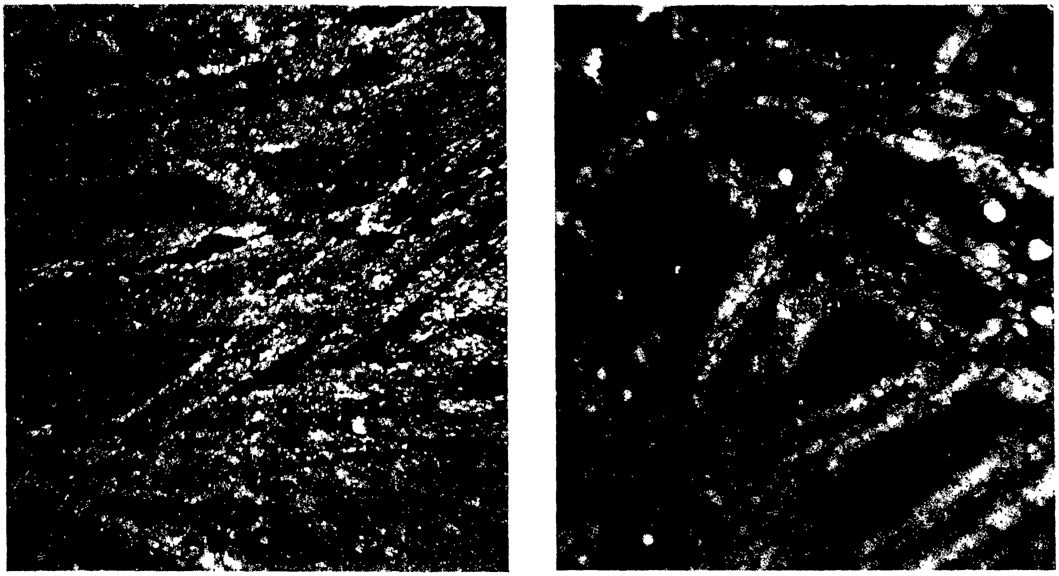


FIG. 3. PHOTOMICROGRAPHS OF A THIN SECTION OF A WOOD-ASH STONE
Left, NOTE ELONGATED CROSS SECTIONS OF CRYSTALS OF POTASSIUM-CALCIUM CARBONATE (×20); *right,* SAME, AT HIGHER MAGNIFICATION (×50), SHOWING LATH-SHAPED CROSS SECTIONS OF PLATY HEXAGONAL CRYSTALS.

and scattering of the ash before it can be heated sufficiently, or sufficient air is supplied to the burning tree to sweep out carbon dioxide as fast as it accumulates.

Even if the stones are successfully produced, they still have perils to face. As long as they are dry, they will persist unchanged. But when they are attacked by water—not energetically, but intermittently with intervening drying—the stone may eventually be thoroughly leached of its highly soluble potassium carbonate component; then the residue, still stony perhaps, or perhaps a powdery mass, will be essentially calcium carbonate and apparently in no way different from a piece of crumbly limestone.

It is conceivable that under special conditions of arid climate a wood-ash stone might be preserved through a long geological time. But ordinarily their lifetime will be short, a matter of years only.

Until their nature was understood, various erroneous ideas were held as to the origin of these stones. As the stones occurred in dense forests where no similar rock was to be found and were obviously too large for transportation by birds or animals, it was conjectured that they might be meteorites. As they were found where there had been fire, it was even surmised that they had caused the fire—another instance of erroneous conclusions from circumstantial evidence.

NATIONAL ACADEMY OF SCIENCES MEDAL AWARDS

By PAUL BROCKETT

DURING a period of seventy years, nine funds were established under the National Academy of Sciences to provide medals and honoraria for the recognition of outstanding scientific work. In the following sections each of the nine medals is illustrated, information is given about the award that it represents, and the recipients of each award are listed. The year of award is not necessarily the year in which the medal was presented. With the exception of the Charles Doolittle Walcott Medal (bronze), all are gold medals, ranging from one and three-quarters to three inches in diameter. The medals are discussed in alphabetical order.

ALEXANDER AGASSIZ MEDAL

Sir John Murray, British geographer and oceanographer, was a guest of the Academy at the Annual Dinner on April 19, 1911, when the Henry Draper Medal was presented to Charles Greeley Abbot for his work on the infrared regions of the solar spectrum and his accurate measurements, by improved devices, of the solar "constant" of radiation. Sir John was so impressed by the establishment of an award for original investigations in astronomical physics that he expressed a desire to found, under the National Academy of Sciences, a similar medal for deep sea researches in honor of his friend, Alexander Agassiz, who had died the year before and who had been the leading American investigator in oceanography.

On April 22, 1911, Sir John Murray wrote the following letter to the Academy:

> I enclose you a cheque for $6,000 (£ 1233) which sum I trust the National Academy will accept from me, for the purpose of founding an Alexander Agassiz gold medal, to be awarded for original contribution in the science of oceanography to scientific men in any part of the world, whenever and as often as the President and the Council may deem desirable.

The Sir John Murray Fund, now amounting to $10,000, was thereupon established. The obverse of the medal bears a three-quarter bust of Alexander Agassiz; the reverse, a swimming medusa, or jellyfish.

Recipients of the Agassiz Medal

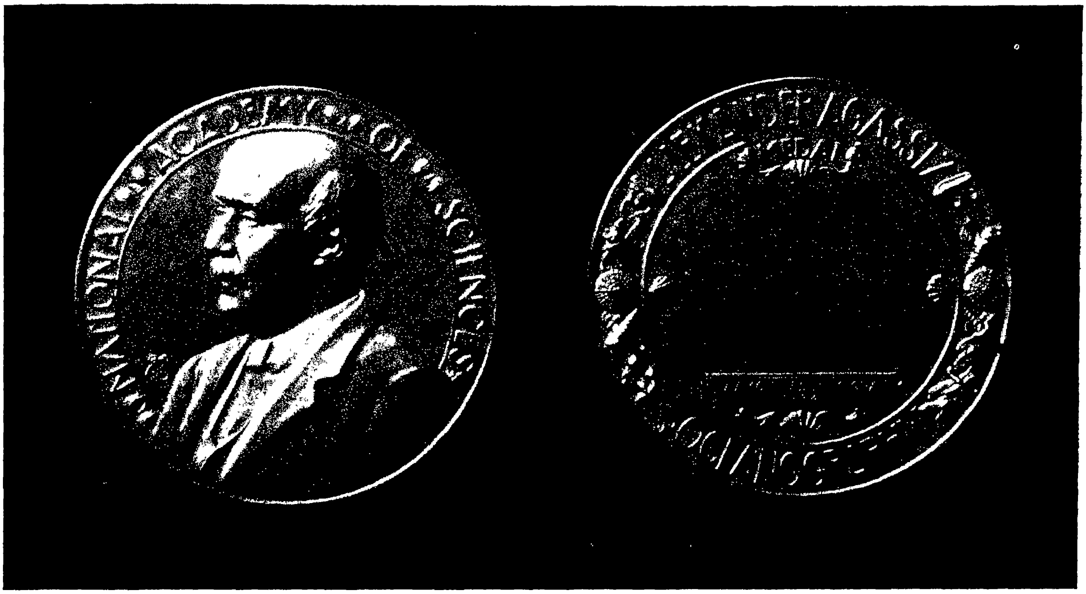
HJORT, JOHAN, 1913
ALBERT I, Prince of Monaco, 1918
SIGSBEE, C. D., 1920
PETTERSSON, OTTO SVEN, 1924
BJERKNES, VILHELM, 1926
WEBER, MAX, 1927
EKMAN, V. WALFRID, 1928
GARDINER, J. STANLEY, 1929
SCHMIDT, JOHANNES, 1930
BIGELOW, HENRY BRYANT, 1931
DEFANT, ALBERT, 1932
HELLAND-HANSEN, BJORN, 1933
GRAN, HAAKON HASBERG, 1934
VAUGHAN, T. WAYLAND, 1935
KNUDSEN, MARTIN, 1936
ALLEN, EDGAR JOHNSON, 1937
SVERDRUP, HARALD ULRIK, 1938
LILLIE, FRANK RATTRAY, 1939
ISELIN, COLUMBUS O'DONNELL, 1942

JOHN J. CARTY MEDAL

The John J. Carty Fund of $25,000 was established in 1930 by close associates of Dr. Carty when he retired from the vice-presidency of the American Telephone and Telegraph Company. They wished to record for all time evidence of their love, respect, and esteem for him and his work.

The medal bears on the obverse a bust of Dr. Carty; on the reverse below the name of the recipient, a flaming conventionalized sun—the great source of energy—with its rays boldly treated. A monetary award is made with the medal. Both are granted for noteworthy and distinguished accomplishments in any field of science coming within the scope and charter of the Academy and are accompanied by a diploma citing the reasons for the award.

It is stipulated that the award shall not be made oftener than once in two years and that no limitation shall be placed on the selection of a recipient by reason of his race, nationality, or creed. The first award was made posthumously to Dr. Carty.



ALEXANDER AGASSIZ MEDAL, OCEANOGRAPHY

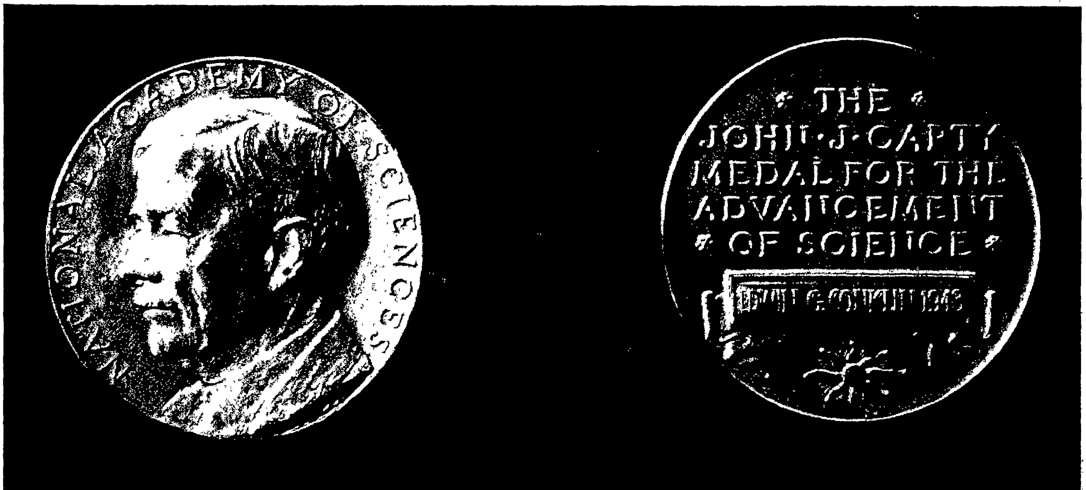
Recipients of the Carty Medal

CARTY, JOHN J., 1932
WILSON, EDMUND BEECHER, 1936
BRAGG, SIR WILLIAM, 1939
CONKLIN, EDWIN GRANT, 1943

HENRY DRAPER MEDAL

In 1883 a fund of $6,000 was presented by Anna Palmer Draper in memory of her husband, an eminent astronomer. It was stipulated that the medal be presented to any person in the United States of America or elsewhere who shall make an original investigation in astronomical physics of sufficient importance and benefit to science to merit such recognition. It was further stipulated that the medal shall not be presented more frequently, on the average, than once in two years, that the investigation for which it is awarded shall be made known to the public, and that the work shall have been completed or published since the time of the last preceding award.

It was also provided that if the income of

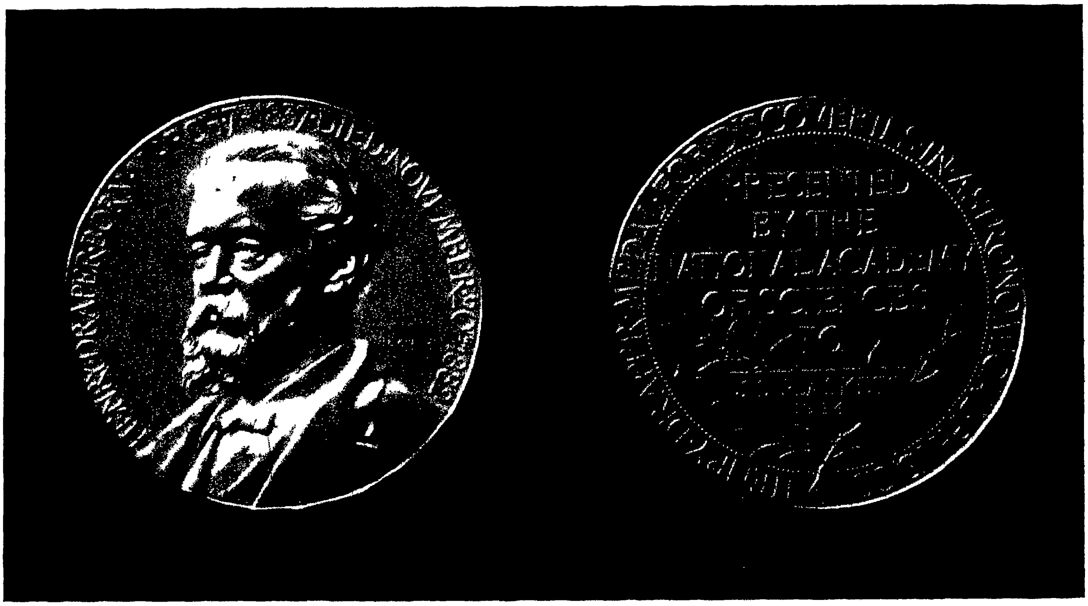


JOHN J. CARTY MEDAL, FUNDAMENTAL SCIENCE

the fund, now amounting to $10,000, shall exceed the amount necessary for striking the medal, the surplus shall be used in such manner as shall be selected by the Academy in aid of investigations in astronomical physics by citizens of the United States.

Recipients of the Draper Medal

LANGLEY, S. P., 1886
PICKERING, E. C., 1888
ROWLAND, H. A., 1890
VOGEL, H. K., 1893
KEELER, J. E., 1899
HUGGINS, SIR WILLIAM, 1901
HALE, GEORGE E., 1904
CAMPBELL, W. W., 1906
ABBOT, C. G., 1910
DESLANDRES, H., 1913
STEBBINS, JOEL, 1915
MICHELSON, A. A., 1916
ADAMS, W. S., 1918
FABRY, CHARLES, 1919
FOWLER, ALFRED, 1920
ZEEMAN, PIETER, 1921
RUSSELL, H. N., 1922
EDDINGTON, SIR ARTHUR S., 1924
SHAPLEY, HARLOW, 1926
WRIGHT, WILLIAM H., 1928
CANNON, ANNIE JUMP, 1931
SLIPHER, V. M., 1932
PLASKETT, JOHN STANLEY, 1934
MEES, C. E. KENNETH, 1936
WOOD, ROBERT WILLIAMS, 1940
BOWEN, IRA SPRAGUE, 1942



HENRY DRAPER MEDAL, ASTRONOMICAL PHYSICS

DANIEL GIRAUD ELLIOT MEDAL

In 1917 Miss Margaret Henderson Elliot gave $8,000 to found a medal and honorarium for the most meritorious work in zoology or paleontology published each year. Thus she carried out a testamentary provision in the will of her father, Daniel Giraud Elliot. The medal, together with an accompanying diploma and any unexpended balance of income for the year, was to be awarded annually.

The obverse of the medal bears a portrait bust of Daniel Giraud Elliot; the reverse symbolizes the field of the award. The object in the center of the reverse is a fossil tree trunk, surmounted by a butterfly and entwined by a snake. At the bottom is a sea shell immersed in waves, perhaps to show in a conventionalized way the beginning of life in the sea, from which, it has been said, all life came.

Recipients of the Elliot Medal

CHAPMAN, F. M., 1917
BEEBE, WILLIAM, 1918
RIDGWAY, ROBERT, 1919
ABEL, OTHENIO, 1920
DEAN, BASHFORD, 1921
WHEELER, WILLIAM MORTON, 1922
CANU, FERDINAND, 1923
BREUIL, HENRI, 1924

DANIEL GIRAUD ELLIOT MEDAL, ZOOLOGY AND PALEONTOLOGY

WILSON, EDMUND B., 1925
STENSIÖ, ERIK A.: Son, 1927
SETON, ERNEST THOMPSON, 1928
OSBORN, HENRY FAIRFIELD, 1929
COGHILL, GEORGE ELLETT, 1930
BLACK, DAVIDSON, 1931
CHAPIN, JAMES P., 1932
LULL, RICHARD SWANN, 1933
PAINTER, THEOPHILUS SHICKEL, 1934
COLBERT, EDWIN H., 1935
MURPHY, ROBERT CUSHMAN, 1936

PUBLIC WELFARE MEDAL

The Marcellus Hartley Fund of $1,200 was established in 1913 by Mrs. Helen Hartley Jenkins in honor of her father, Marcellus Hartley, for the founding of a medal to be awarded by the National Academy of Sciences for eminence in the application of science to the public welfare—in these words:

Patriotism and justice alike demand that certain public services involving the application of science should receive a conspicuous recognition at the hands of the National Academy of Sciences.

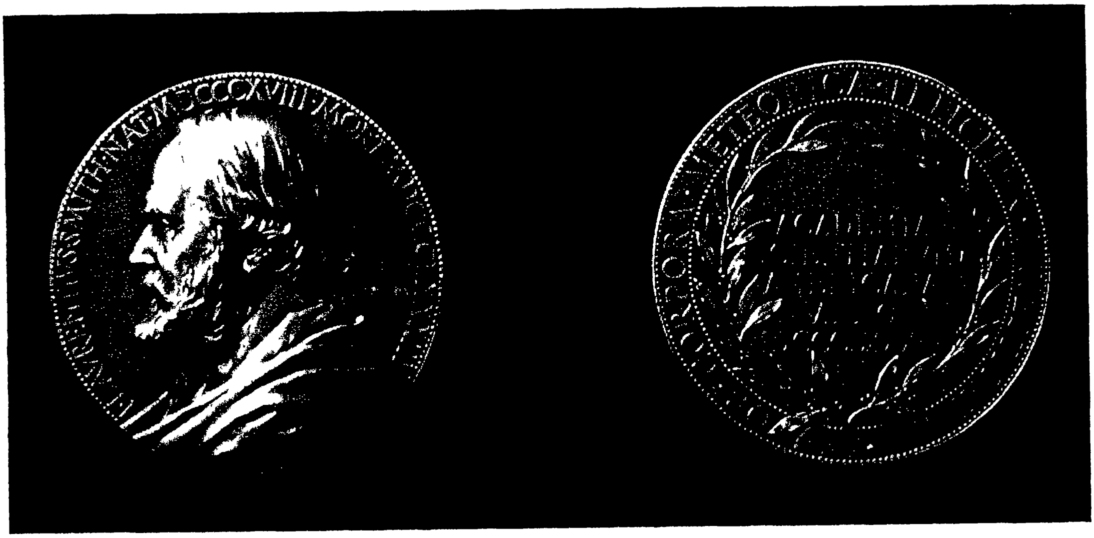
It is the purpose of the Public Welfare Medal to mark the appreciation of the National Academy for eminent services to the public, performed without a view to great monetary gains and by methods which, in the opinion of the Academy, are truly scientific.

PUBLIC WELFARE MEDAL, APPLIED SCIENCE

On the obverse of the medal is the figure of Archimedes with one foot in space and the other foot on his helmet. He is straining with both hands on a lever pressing against the universe, which is shown as a segment of a sphere. The whole design gives the sculptor's conception of the application of science to the public welfare. The quotation in Greek is the celebrated saying of Archimedes: "Give me where I may stand and I will move the world." On the segment of the sphere are the symbols of Taurus and Leo, together with a cluster of stars.

$10,000 was established by his wife, Sarah Julia Smith, in his memory. It was stated that the medal may be awarded to any person in the United States or elsewhere who shall make an original investigation of meteoric bodies of sufficient importance and benefit to science to merit such recognition.

The Latin inscription about the bust of J. Lawrence Smith gives the years of his birth and death, 1818–1883. On the obverse is a laurel wreath arranged as a crown. The Latin reads: For fruitful research in meteoric bodies.



J. LAWRENCE SMITH MEDAL, METEORIC BODIES

Recipients of the Welfare Medal

GOETHALS, G. W., 1914
GORGAS, W. C., 1914
ABBE, CLEVELAND, 1916
PINCHOT, GIFFORD, 1916
STRATTON, S. W., 1917
HOOVER, HERBERT, 1920
STILES, C. W., 1921
CHAPIN, CHARLES V., 1928
MATHER, STEPHEN TYNG, 1930
ROSE, WICKLIFFE, 1931
PARK, WILLIAM HALLOCK, 1932
FAIRCHILD, DAVID, 1933
VOLLMER, AUGUST, 1934
RUSSELL, F. F., 1935
CUMMING, HUGH S., 1935
WHITNEY, WILLIS RODNEY, 1937
HOOVER, JOHN EDGAR, 1939
ROCKEFELLER, JOHN DAVISON, 1943

J. LAWRENCE SMITH MEDAL

In 1885 the J. Lawrence Smith Fund of

Recipients of the Smith Medal

NEWTON, H. A., 1888
MERRILL, GEORGE P., 1922

MARY CLARK THOMPSON MEDAL

The Mary Clark Thompson Fund of $10,000 was established in 1919 to honor the most important services to geology and paleontology. Mrs. Thompson became interested in the establishment of this fund through John Mason Clarke, who informed her that no great reward was available at that time for extraordinary contributions to geology or paleontology.

The obverse of the medal shows the sculptor's conception of geological and biological origins. The churning waves denote the sea; the rocks, upheaved in an anticlinal position from the sea, symbolize the birth of the

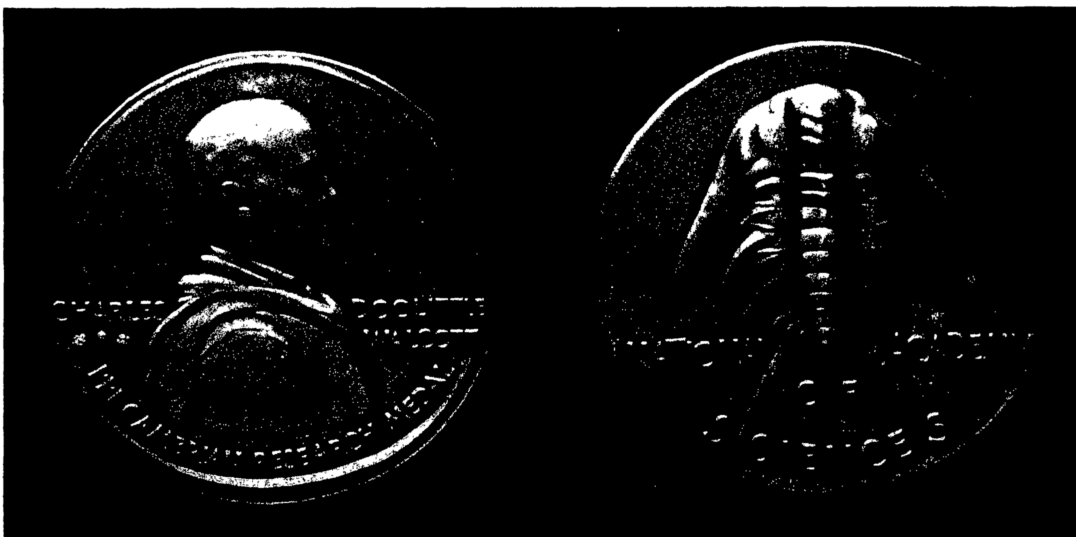
MARY CLARK THOMPSON MEDAL, GEOLOGY AND PALEONTOLOGY

world. The commotion extends to the atmosphere, creating clouds. Topping all is life, depicted by the nude figure of a woman looking toward the sun, which gives light to the new world for the future.

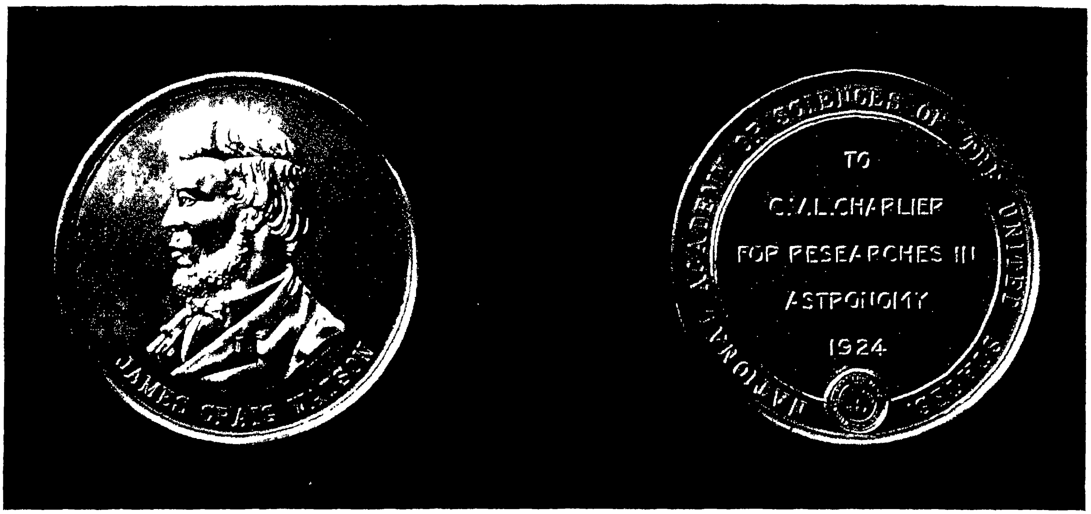
The reverse of the medal depicts a balance in which ore, crucible, and hammer outweigh the knowledge of the world in the form of manuscript and book. The legend reads: Explore everything; hold fast to the good. On the edge of the medal (not shown in the illustration) are pressed a conventional pattern of lines enclosing the words: *Virtute et Constantia* (Courage and Perseverance).

Recipients of the Thompson Medal

Walcott, Charles Doolittle, 1921
Margerie, Emmanuel de, 1923
Clarke, John Mason, 1925
Smith, James Perrin, 1928
Scott, William Berryman, 1930
Ulrich, Edward Oscar, 1930
White, David, 1931
Bather, Francis Arthur, 1932



CHARLES DOOLITTLE WALCOTT MEDAL, PRE-CAMBRIAN LIFE



JAMES CRAIG WATSON MEDAL, ASTRONOMY

SCHUCHERT, CHARLES, 1934
GRABAU, AMADEUS WILLIAM, 1936
WATSON, D. W. S., 1941
WOODWARD, SIR ARTHUR SMITH, 1942
SIMPSON, G. G., 1943

CHARLES DOOLITTLE WALCOTT MEDAL

The Charles Doolittle Walcott Fund of $5,000 was established in 1928 to encourage and reward individual achievement in advancing our knowledge of Pre-Cambrian or Cambrian life in any part of the world. It provides for the award of medals and honoraria to persons whose published researches, explorations, and discoveries in Pre-Cambrian or Cambrian life are worthy of the highest recognition. The awards shall be made without respect to nation, race, sex, or academic degree, on the recommendation of a board of five members, known as the Charles Doolittle Walcott Trust Fund Board, composed as follows: One ex-officio member, who shall be the Secretary of the Smithsonian Institution; two members eminent in the paleontology of early Paleozoic formations, one member to be appointed by the Institut de France and one by the Royal Society of London (each of these organizations should at all times have one representative on the board); two members distinguished in Paleozoic paleontology, to be appointed by the president and council of the National Academy of Sciences of the United States of America.

This medal is bronze, and it was stipulated that if bronze were not available, any other inexpensive metal could be used because the honorarium is the feature of this award. On the reverse of the medal is a trilobite.

Recipients of the Walcott Medal

WHITE, DAVID, 1934
WESTERGAARD, A. H., 1939

JAMES CRAIG WATSON MEDAL

The James Craig Watson Fund of $25,000 was the first medal fund established under the National Academy of Sciences, in 1874. It has been used not only to provide a medal and honorarium for the recognition of outstanding astronomical research but also to promote astronomical science by supporting research and publication of results.

Recipients of the Watson Medal

GOULD, B. A., 1887
SCHOENFELD, ED., 1889
AUWERS, ARTHUR, 1891
CHANDLER, S. C., 1894
GILL, SIR DAVID, 1899
KAPTEYN, J. C., 1913
LEUSCHNER, A. O., 1915
CHARLIER, C. V. L., 1924
DE SITTER, WILLEM, 1929
BROWN, ERNEST WILLIAM, 1936

TELEGRAPHS AND TELEGRAMS IN REVOLUTIONARY FRANCE*

By DUANE KOENIG

FROM time immemorial men have sought to communicate their ideas rapidly over vast distances. To this end they have experimented with devices ranging from the pigeon post to the pony express One of the first of the modern inventions for quick correspondence between widely separated points was the optical, or aerial, telegraph. This was the work of Claude Chappe, à French engineer, assisted by his four brothers, Ignace, Pierre, René, and Abraham.

Claude Chappe was born at Brûlon, now in the Sarthe department, in 1763. He inherited from his uncle, a celebrated eighteenth century astronomer and traveler, the abbé Jean Chappe d'Auteroche (1722–1769), his passion for science and his indefatigable ardor for work. Early in life he applied himself to physics and mathematics and by the age of twenty was contributing articles to learned scientific periodicals. In 1790 he became interested in the problem of signaling friends who lived several miles away from his home. Adapting an idea of Guillaume Amontons, a scientist who lived at the end of the seventeenth century, Chappe developed machines which he called telegraphs; these were capable of making recognizable signs by means of dials and pendulums. They worked so well that Chappe was able to offer a demonstration for the officials of the municipality of Parcé in the Sarthe. In the presence of these functionaries on March 2 and 3, 1791, Chappe transmitted accurately and in a matter of minutes, messages from Parcé to Brûlon, a distance of more than a dozen miles. Having been given sworn affidavits attesting his experiments, Chappe set out to seek the support of the government for the erection of a telegraph line.

Shortly thereafter his older brother, Ignace Urbain Jean, was elected a deputy to the Legislative Assembly at Paris. Probably through Ignace's influence, Claude was able to address that body on March 24, 1792, and inform it that he with the help of his brothers had built machines which could signal with such speed that if telegraph lines were set up the Assembly could send messages to any of France's frontiers and receive replies during a single afternoon's sitting. He submitted the affidavits of the Parcé officials as evidence of his contentions. The Assembly listened to Chappe and admitted him to the honors of the meeting. As for the matter of building a telegraph line, that was referred to the Assembly's committee of public instruction.

The Legislative Assembly expired in the turbulent days of September, 1792, without having taken any action on the telegraph. Accordingly, on October 9 following, the inventor laid before the newly elected National Convention a petition for consideration of his discovery. The National Convention accepted the petition and referred it to the committees of war and marine.

The Chappe brothers had to face not only legislative indifference but also public antipathy to their experiments. During the latter part of 1791 they obtained permission to make demonstrations at Paris and place their telegraph apparatus on one of the pavillions in the enclosure of the *Étoile*. Their machine was pulled down one night shortly after its completion by persons unknown, and it was so demolished as to be of no further use. A few months later a telegraph station was set up in the LePeltier Saint-Fargeau park at Belleville. The burghers of Belleville apparently believed that attempts were being made to communicate with the Austrians and Prussians, for a mob collected in the park and burned the telegraph to the ground. Only the warnings of friends kept the Chappes away from the scene and possible mob violence.

To make sure that further undertakings

* The manuscript of this article was thoroughly documented by the author, but his citations were deleted at the request of the editors. Those who wish to know the sources of information and of illustrations should write to the author.

CLAUDE CHAPPE, 1763–1805
INVENTOR OF THE OPTICAL SEMAPHORE TELEGRAPH.

would not be destroyed by the fury of the populace, Claude Chappe sent a letter on October 15, 1792, to the Convention, asking that he be authorized officially to rebuild his instruments at Belleville. When the letter was read by the secretary of the National Convention, the Deputy Rabaut de Saint-Étienne suggested that the petition be turned over to the committee of public instruction. The Convention so ordered.

It was not until April 1, 1793, that a representative of the committee of public instruction, Gilbert Romme, rose to the tribune of the Convention and spoke on behalf of the Chappe brothers. Romme pointed out that several systems of communication had been presented to the government, but that Citizen Chappe's was the only one which seemed to merit any attention. He described the Sarthe experiments and suggested that before approving the construction of any lengthy telegraph lines, the Convention appropriate 6,000 francs from the general funds of the war department to determine the workability of the telegraph. The deputy then presented a project of law to this effect which was approved by the Convention. Five days later the committee of public instruction suggested that the Deputies Joseph Lakanal and Pierre Claude François Daunou be appointed to observe and report on the functioning of the new stations. This proposal was accepted.

That public opinion continued skeptical of the telegraph is patent from the fact that on July 2, 1793, Lakanal reported on Chappe's progress and offered the Convention a bill ordering the mayors of the communes where telegraphs were being erected, to prevent damage from being done to the machines. This decree was forthwith voted. With the legislative appropriation the Chappe brothers constructed three telegraph stations, one on the old location in the LePeltier Saint-Fargeau park at Belleville, a second on the heights of Écouen, and a third at Saint-Martin-du-Tertre.

As perfected, their telegraph consisted of a post 30 feet high, with a movable crosspiece, or regulator, attached at the top. The regulator was 14 feet long, 13 inches wide, and 1½ to 2 inches thick. At each end of the crossbar was an indicator 6 feet long, 1 foot wide and 1 inch thick. Steel rods with lead counterweights were attached to the bases of the indicators to balance them. The two indicators and the regulator were connected by a system of pulleys to the base of the post so that they could be moved to any desired position. For visibility, the machine was painted black.

The apparatus did not spell out words in the fashion of its successor, the electric telegraph. Each sign made represented either a word or phrase, or the number of a word or phrase in the table of signals. This reduced the number of signals necessary for sending any message. The regulator could take any one of four major positions: horizontal, vertical, 45 degree tilt to the right, 45 degree tilt to the left. The indicators were capable of being used in any of seven different positions, each 45 degrees from the next. The only position not used was that of the indicator being extended straight out as a prolongation of the regulator. This signal could not be seen distinctly. Hence the telegraph could make 196 different signals. To further

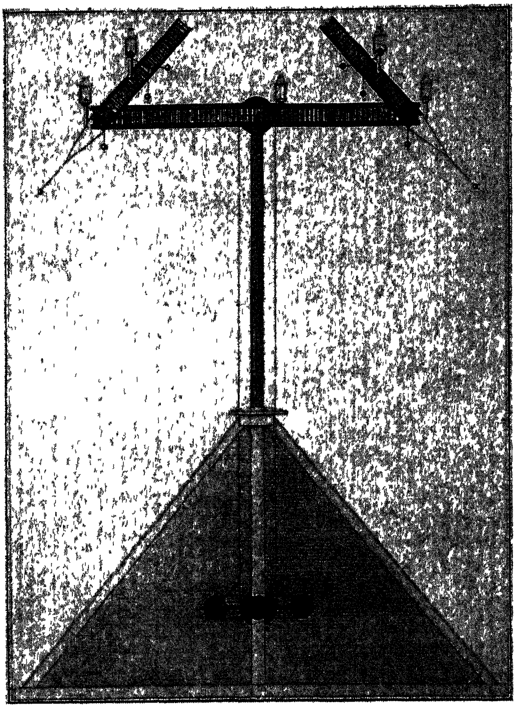
simplify matters, the levers at the base of the machine which operated the crossbar and arms always took in the signaling the same positions as the regulator and indicators.

An innovation in the communication was that, instead of sending the entire message from one station to the next, Chappe planned to send his messages one letter, word, or phrase at a time down the entire line. Thus station *A* would send the first signal. As soon as the agent at station *B* could see through his telescope the sign made by *A* and move the levers of his telegraph to the correct position, the signal would be flashed to station, *C*. While station *C* would be transmitting the signal on to *D*, the first station would be in the process of sending the second signal. Like waves the signals would follow one another down the line. Experience showed that if signals were transmitted faster than three a minute, errors became inevitable.

Chappe and his brothers realized that the entire system could never be stronger than its weakest link. An inattentive agent might make mistakes which would take time for correction, or by his absence from duty delay transmission for hours. Once the telegraph was established, agents were paid about 25 sous a day, and deductions were made from their pay for every minute of tardiness or for lack of attention. Ignace Chappe said that as far as possible the telegraphers should be "simple men without intrigue."

An ex-consul, Léon Delaunay, who was experienced in the ciphers and codes of diplomacy, assisted the Chappes in the preparation of their signals. Of the dispatch signals 98 were devised for the handling of messages and 98 others for the regulation and policing of the line. These latter were necessary to indicate attention, the direction the signals would move down the line, beginning or end of a message, interruption of a dispatch for a new one, cancellation of the original dispatch, difficulties on account of weather, failure of equipment, or absence of agents. And each station had its own signal to locate it if breakdowns occurred.

On July 12, 1793, before the representatives of the committee of public instruction and several scholars and artists, the first telegraph line was demonstrated. Daunou took up his place at the Belleville station, while

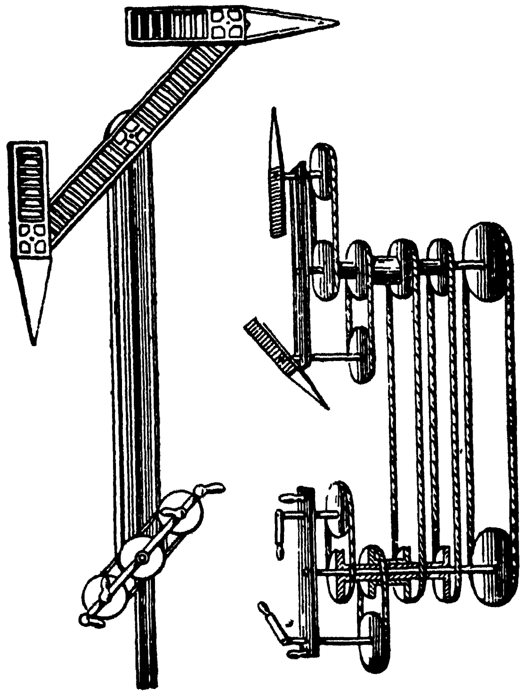


THE CHAPPE TELEGRAPH
EQUIPPED WITH LAMPS FOR SIGNALING AT NIGHT.

Lakanal and a Citizen Arbogast went to Saint-Martin-du-Tertre. At 4:26 P.M., activity signals were made and in eleven minutes Daunou was able to transmit to Lakanal, almost a score of miles away, the message: "Daunou has arrived here. He announces that the National Convention has just authorized his committee of general security to put seals on the papers of the deputies." It took only nine minutes for Lakanal to reply, "The inhabitants of this beautiful region are worthy of liberty by their respect for the National Convention and its laws." Successful communication was continued for some time until the Écouen station signaled that it was unable to dispatch further messages.

Lakanal made a formal report to the Convention on August 14 following. He stressed particularly the accuracy of the telegraph and emphasized the fact that only people knowing the codes, which could be changed at any time, would be able to intercept messages. The most secret dispatches might be sent with only the first and last stations on the line understanding the meaning of the

ciphers. The committee of public instruction recommended that a sum of 58,400 francs be appropriated for the construction of a line from Paris north to Lille, on the frontier of the Austrian Netherlands. This line would consist of sixteen stations, averaging about 6,000 francs each in cost. With certain economies the total amount necessary might be reduced from 96,000 to 58,400 francs. This project of law passed the Convention, and in recognition of his work



THE CHAPPE TELEGRAPH
ILLUSTRATING THE SYSTEM OF LEVERS AND PULLEYS USED TO OPERATE THE REGULATOR AND INDICATORS.

Claude Chappe was granted the titles of telegraph engineer and engineering lieutenant in the army. He and his brothers Ignace and Pierre François were named administrators of the telegraph line.

The choice of locations for stations required great care, because faulty sites would affect the whole line. After stations were set up, they sometimes had to be relocated and the direction of the line changed. Almost a year was required before the proper route could be determined and the telegraph instruments erected between Paris and Lille. The stations were finally completed by midsummer of 1794. The first news sent from Lille to Paris was that of General Scherer's recapture of LeQuesnoy from the Austrians and Prussians on August 15, 1794. On August 17, the Deputy Bertrand Barère de Vieuzac announced the victory and added: "We seize upon this occasion to speak to you of a new establishment made under the auspices of the National Convention, of a machine by means of which the news of the recapture of LeQuesnoy was brought to Paris, an hour after our garrison re-entered the town." He then reviewed the history of the telegraph in almost panegyric tones: "Modern peoples by printing, gunpowder, the compass and by the language of telegraph signs, have made vanish the greatest obstacles which have opposed the civilization of men, and made possible their union in great republics. It is thus that the arts and sciences serve liberty."

A fortnight later the telegraph brought the news of the recapture of Condé The Convention received word at 1 P.M. on September 1 and immediately sent to Lille a message of congratulations and a decree changing the name of Condé to Nord-Libre. Before the end of the afternoon session, the Convention had received from Lille an acknowledgment of the message.

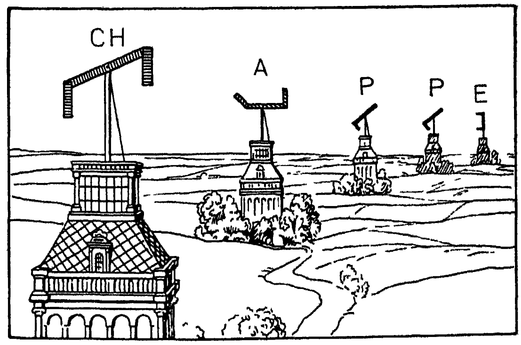
The success of the Paris-Lille line brought a flood of enthusiasm and ideas for new lines and new types of telegraphs. In 1795 the committee of public safety began the construction of a telegraph line from Paris to Landau. To call for help in the event of an attack on the Thermidorian Convention by the Paris mob, the first station of the Landau line was located on the pavillion of *Unité* of the Tuileries near the national alarm bell. A mechanic, a harbormaster, and a mathematics professor collaborated in the construction of a signaling machine called the "vigigraph" and obtained money from the Directory to build a line from Paris to LeHavre. The vigigraph consisted of a ladder raised into the air with two fixed crosspieces. A movable disk on one side of the ladder and a movable regulator on the other side made signaling possible by their relation to each other. One of these instruments was erected on the tower of the Church of Saint-Roch at Paris. It remained there unused for a long

time before being removed to gather dust in the storerooms of the telegraph administration building. No other stations of the projected vigigraph line were ever built.

In 1797 Chappe extended a line from Paris to Strasbourg and located the final station on the Strasbourg cathedral. This chain of stations began operations the next year, reporting the news from the Germanies brought to Strasbourg by the Rastatt courier. The line was lengthened to Huningue in 1799. The Lille telegraph was carried to Dunkerque in 1798 and at the same time a line was built from Paris to Brest via Saint-Malo. Another addition to the Paris-Lille network came in 1803 with a branch to Brussels and one to Boulogne. Other extensions were to Anvers and Flushing in 1809 and to Amsterdam in 1810 In 1797 the Directory authorized a line to the south of France, but actually stations were only built as far as Dijon. It remained for Bonaparte to order telegraphic communication between Paris and Milan, the capital of his Italic kingdom Five years later, in 1810, Milan and Venice and shortly afterwards, Mantua, were connected by telegraph.

The Directory built a few mobile telegraphs for the army until the funds allotted for these units ran out. Bonaparte took up the idea and at the time of the war with Russia attached Abraham Chappe to his staff to direct the use of the telegraph for military purposes. The use of the semaphore telegraph, which under favorable conditions could send a message from Paris to Venice in half a dozen hours, contrasted very favorably with a signal flag system Napoleon ordered in 1809 to communicate between his military headquarters at Vienna and Strasbourg. Bonaparte apparently believed that the mere stationing of men at regular intervals with signal flags would suffice to send messages. Created without regard to scientific location of stations, this line was never able to transmit messages successfully.

Claude Chappe found the path of the inventor a thorny one. On every side he met rivals claiming to have invented telegraphs and seeking a share of the credit for the invention. A watchmaker named Bréguet and his associate Bétancourt so discouraged Chappe by their quarrels with him over the

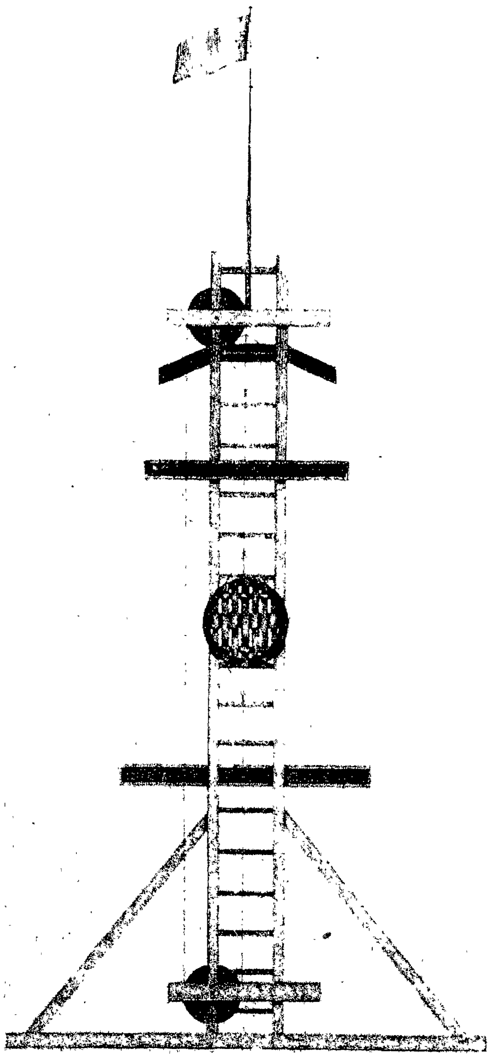


THE TELEGRAPH STATIONS
PLACED ON HILLS EIGHT TO TWELVE MILES APART.

priority of his ideas that he committed suicide on January 23, 1805. Direction of the telegraph continued in the family after Chappe's death. When Louis XVIII was restored to the throne of France in 1814, he granted Ignace, Pierre, and Abraham the rank of chevaliers of the Legion of Honor. These favors from the hands of the Bourbon were sufficient to give currency to the rumors during the Hundred Days that the Chappes were under arrest. To clarify the situation, the brothers felt obliged to write the editor of the official *Gazette Nationale ou le Moniteur Universel* to point out that while a military post had been established in the offices of the telegraph administration, it was to protect the telegraph and not to arrest the Chappes. The letter was published on March 17, 1815.

The Bourbons constructed numerous telegraph lines. By the time the electric telegraph was introduced in 1844, there were some 534 optical telegraph stations and more than 3,000 miles of line serving 29 of France's largest cities and towns. In 1816 a line was constructed from Paris to Calais. A line from Lyons to Toulon began operation at the end of 1821 and replaced the old line of Napoleon's to southern France. The capital and Bordeaux were connected in 1823, via Orléans, Poitiers and Angoulême. The same year also saw Bayonne brought into telegraphic contact with Paris and by 1828 a line from Avignon to Perpignan via Nîmes and Montpellier was in action.

From the opening of the Lille line in 1794 and for five years thereafter, the telegraph administration was controlled by the engineering division of the war ministry. From



THE VIGIGRAPH
AN IMPRACTICAL TELEGRAPH, REVOLUTIONARY PERIOD.

1799 to 1830 it was under the minister of the interior. In 1823 King Louis XVIII retired Ignace Chappe on a pension of 4,255 francs and Pierre on an income of 2,252 francs. The younger brothers, René and Abraham, remained in charge of the telegraph thereafter. The eldest Chappe died on January 26, 1829, at Paris. Two days after his death his three surviving brothers felt forced to deny publicly that the monarchy had allowed him to die destitute. From 1830 until May 28, 1831, the telegraph was in the public works administration; then it went back to the interior ministry. The Chamber of Deputies passed a bill on March 14, 1837, and the Chamber of Peers on April 17 following, which made the telegraph a government monopoly and provided fines of 1,000 to 10,000 francs for any person or persons transmitting telegraph signals without government authorization. The last report of a new optical telegraph line was that of the Paris-Agen system which was put in operation in August, 1844, and could send dispatches of medium length to the capital city in fifteen minutes. The year 1844 also saw the inauguration of the Paris-Rouen electric telegraph line. The telegraph stations in France were never co-ordinated into a really effective network which could carry orders from the Paris government to the capitals of all of the departments in a matter of minutes. Indeed, it was not until 1823 that the telegraph was reported as being used to bring news from the capital to the provinces and handle other than army or diplomatic matters.

Night telegraphy was much more difficult than day telegraphy and the results obtained were much less satisfactory. As early as October 18, 1794, the National Convention received suggestions from a citizen for using the telegraph at night. The Chappe brothers hung lanterns 8 inches wide and 12 inches high to the arms and crosspiece of their machine. There were two lamps on each indicator and one on the regulator. For three years the telegraph on the dome of the Louvre was equipped with such lamps. When Napoleon was plotting his invasion of England and wanted night communication with Boulogne, a telegraph with only one indicator was devised. The indicator and regulator were hung with three lanterns 16 inches in diameter equipped with parabolic reflectors. Although incapable of the number of signals the day telegraph could give, it was workable.

In 1822 a day and night telegraph was constructed between Paris and Bordeaux by Rear Admiral Saint-Haoun. The heir to the Bourbon throne, the Count of Artois, was interested in the project and on October 23, 1822, was present at a demonstration of correspondence between Montmartre and Orléans. The experiment worked to the full satisfaction of Monsieur. This episode brought a

sharp letter to the *Moniteur* from Ignace Chappe who denounced Saint-Haoun's undertaking as "a very imperfect attempt," and added: "It has been 29 years that the telegraph has actually been in use now, taking not more than a minute per word to transmit messages more than a hundred leagues. . . . When the government will desire it, we will use the telegraph with the same speed, *night* as well as day."

The fact that the night telegraph never worked very well constantly brought forth new ideas for night signaling. The inventor Jules Guyot proposed that the Chappe telegraph be adapted for night signaling by hanging two white lanterns at the ends of the regulator and a green lantern at the end of each indicator. He also conceived a night telegraph using two hydrogen lanterns. This device was never established practically. In 1831 one Ferrier de Tourettes went to England to promote a two-lamp telegraph which he said would be able to work with stations eighteen miles apart. No system of night telegraphy ever came into general use, and it was for the Morse invention to provide instantaneous night communication.

Although the scope of this paper is the development of the optical telegraph in France, it should be observed that this means of communication was tried elsewhere with varying success. In 1794 the Swedish scientist Endelerantz invented a telegraph consisting of a block of ten rectangular panels, each panel turning on an axis. By opening and closing these panels in various combinations, he was able to signal intelligibly. He made his first public demonstrations between Drottningholm and Stockholm on October 30, 1794. Two years later a short line of three of these telegraphs was put in use in the Aland Islands.

The British used a modification of the Endelerantz system, a telegraph with six panels. In 1796–97, London and Dover, London and Sheerness, and London and Plymouth were connected. The Admiralty building in London was the headquarters for the telegraph network. A year later it was reported that the British were making portable telegraphs for use with forces engaged in putting down the Irish rebels.

The Chappe telegraph was also very popular outside of France. A line was projected in 1801 from Basle to Augsburg by the French military authorities, and in 1802 a line was built in Denmark. The British in India constructed a line from Calcutta to Chunar, a distance of 336 miles. Messages could be sent from one end of the line to the other in twelve minutes. The next year the energetic Egyptian Sultan Mohammed Ali built a line of nineteen stations between Alexandria and Cairo which could carry signals between the two cities in four minutes.

The Prussian government spent 170,000 thalers on a line of telegraphs from Berlin to the Rhenish provinces, via Potsdam, Magdeburg, Cologne, Coblenz, and Trier. The Prussian telegraph had six semaphore arms; when it was put in operation in 1832, it was under the control of the war ministry and handled only government messages. Not to be outdone, the Czar Nicholas I of Russia ordered a series of telegraph towers between St. Petersburg and Warsaw. There were 220 stations, each requiring six operators. Thus more than 1,320 men were needed to carry the first message on April 12, 1839, which announced that the Czarina had just recovered from a serious indisposition. From 1844 to 1859 an aerial telegraph existed in Algeria.

The opening of the Paris-Rouen electric telegraph line in 1844 brought the Chappe system to an end. The optical telegraph lasted fifty years and during this period provided France with a faster and more dependable means of signaling than had ever been used anywhere previously. Perhaps the best summation of the work of the inventor Claude Chappe was the statement in the *Moniteur* on January 28, 1805, which announced his death: "People rightly say that the signaling art existed long before him. What must be added to be just and impartial, is that he made of this art an application, so simple, so methodical, so sure and so universally adopted, that he can be regarded as an inventor." On the centennial of the telegraph in 1893, a statue to Claude Chappe was erected in Paris at the intersection of the boulevards Saint-Germain and Respail and the rue du Bac.

A. A. MICHELSON VISITS IMMANUEL KANT

By A. BOYAJIAN

In the ages when people believed in ghosts inhabiting everything, there was no conflict between intelligence and matter, none between purposeful action and physical necessity. But ever since ghosts have been driven out of things by a reign of law in nature, intelligence and purposeful action have been steadily crowded out of the physical world by matter and physical necessity; and the human soul, as the last of the ghosts, has been reduced to an insecure, furtive existence.

What does science say about the matter?

What does philosophy?

Although science does not openly teach anything about this specific subject, yet it insinuates enough. Philosophy does discuss it freely but obscurely, and few people ever hear about it. We will review some of these insinuations and teachings, and attempt to evaluate them. For properly evaluating opinions, we will want to know the competence of the source of the opinion and the validity of the method by which the opinion has been arrived at.

All sciences are systems of thought constructed out of certain assumptions held together by a framework of reasoning. This is very clear in the case of mathematics, which starts with certain assumptions called postulates and works up to a series of conclusions called theorems. By the authority of a tradition of long standing, which may be called mathematical license (after poetic license), postulates are privileged things and may not be questioned except on grounds of inconsistency. For a long time they were even called axioms. Evidently, mathematics is an exact science only in the steps of reasoning from postulate to theorem; it can be real or unreal depending on one's choice of postulates.

The physical sciences are subject to greater discipline in their premises but less so in their reasoning from postulate to theorem. The postulates of the physicist are his data, and these may not be assumed freely under any kind of license but must be obtained by certain traditional methods of experiment and observation. Data so obtained may not be questioned and are supposed to assure "reality," but they open the door wide to contradictory postulates. Evidently, a system of thought based on data which are under no obligation to be consistent among themselves cannot be exact in the mathematical sense but must win temporary acceptance by making the best sense out of the mass of disorganized raw material, and perhaps by occasionally foreshadowing — predicting — things that can be verified by test.

The usual pattern of any progress in the physical sciences is therefore (a) a new set of data at variance with previous ideas, (b) a new hypothesis, (c) a theory, (d) predictions and further tests, (e) a temporary law of nature. The common laws of the physical sciences must be acknowledged as tentative: think of what happened to Newton's "law" of gravitation, the individual "laws" of conservation of mass and conservation of energy, and Maxwell's "laws" of electricity and magnetism in the Lilliputian world of electrons and protons. Tentative or not, these laws had the far-reaching result of establishing a belief in physical necessity which is of paramount importance for our subject. Physics teaches us that the universe is made up of electrons, protons, neutrons, and quanta obeying certain laws, some pretty well known, others to be clarified further, but, whatever the exact formula may be, the picture is one of blind (unconscious) matter tossed about by blind (unpurposeful) forces in obedience to blind (meaningless) physical laws.

The physicist carefully avoids the embarrassing philosophical implications of these theories with respect to man, God and immortality, and other philosophical questions, but these have to be faced sometime or other.

In a brain consisting of electrons, protons, neutrons, and quanta, how is consciousness

possible? For such a brain, how is purposeful action possible? Also, how is knowledge of things in themselves possible? Does the brain secrete thought as the liver secretes bile? In the functioning of the brain, do the electrons, etc., obey the same laws as elsewhere? If so, are freedom and purposeful action a delusion? Does thought have no effect at all on the physicochemical processes in the brain?

The rank materialist (he calls himself a determinist) takes the position that consciousness is an "epiphenomenon"—a surface phenomenon—an appearance, a foam, on the stream of the physical processes in the brain, with no more effect on these processes than the man in the moon has on the moon's movements. A ludicrous aspect of this extreme attitude is that the judge is denying his own reality. Descartes turned the tables on these extremists by his famous syllogism, "I think, therefore I am." It might have been still stronger if he had said, "I doubt, therefore I am." Few scientists profess such materialistic views nowadays. Most people feel that this picture of the universe depicted by science is inadequate. How can it be improved without becoming unscientific?

The oldest theory of escape from scientific fatalism is that man consists of matter and of mind as two independent realities working together in the brain. The matter in the brain obeys natural laws, but in the complex organic reactions of the brain there are conditions of neutral or unstable equilibrium on which occasions the mind can control the direction of the processes one way or another without having to expend any physical energy which, of course, it does not have. So the freedom of the mind and the necessity of physical processes in the brain are reconciled.

To draw an analogy, the mind controls the brain and the body as relays do in electrical and mechanical systems. Control by relays contemplates changing the course of physical events without contributing any matter or energy to the phenomena under control, and yet the theory of relays is not inconsistent with the law of conservation of energy or the physical necessity that governs the electrical and mechanical phenomena.

To draw another analogy, catalysts divert chemical reactions into directions which would not otherwise be followed, and yet catalysts contribute neither material nor energy to the reaction product, and the control they exercise is not considered as in conflict with the laws of conservation of energy and matter or with the law of physical necessity.

This line of thought has been given further encouragement by Heisenberg's Principle of Uncertainty about the position and velocity of electrons. This theory says that when either the position or the velocity of an electron is determined, the other is merely a matter of probability, never of certainty; and that this situation arises not from our ignorance of the facts, but from our knowledge that the facts themselves exist in nature only as probabilities. Some scientists have interpreted this as meaning that nature is not really controlled by the law of cause and effect, as matter in the gross seems to be; that natural laws are only *probable* laws, highly probable in the gross, less and less so in the minute.

A serious objection to this theory of escape is that the relationship of the mental process, which is continuous, to the physical brain process, which also is continuous, must be a continuous one. An occasional interaction between mind and matter at times of unstable equilibrium is not acceptable.

As to the so-called Principle of Uncertainty, the applicability of the law of probability to the electrons cannot exempt them from the law of physical necessity any more than the many other phenomena in nature to which the law of probability is applied.

Another serious objection is that it does not explain how a nonmaterial thing like the mind can react on a nonmental thing as matter. After all, relays and catalysts are material things and constitute a portion of the larger material system which they form in combination with what they control, and the whole system follows physical necessity without a break, without a surprise, without an intrinsic uncertainty. Moreover, catalysts do enter temporarily into the reactions which they control, and they do so by virtue of their surface energy.

A further objection is that it does not explain how the future outcome of a physical process can be predicted by a purely mental process. If mind and matter are separate realities, it must be a miracle that the consequences of physical necessity and the conclusions of logical necessity should correspond to each other.

I think we will agree that this is the old ghost theory in new dress restricted to the brain, scientific in appearance but only a pseudoscience.

It has been attempted to avoid the major difficulty of the foregoing theory by boldly assuming that mind is something like energy and is involved in all physical phenomena—in the rusting of a nail as well as in the brain process that represents philosophical speculation. A number of scientist-philosophers, including Steinmetz, have held this view. According to it, a chemical reaction, for example, is determined by three factors, not two: matter, energy, and mind. In the early days of chemistry, the matter involved in a reaction was considered as the main thing, the accompanying energy was treated as an incidental by-product, as if it had no effect on the reaction, and so it was left out of the equation. Accordingly, the reaction of hydrogen and oxygen to form water was written as

$$2H_2 + O_2 = 2H_2O$$

We recognize today, however, that energy relations are a controlling factor in reactions, and the foregoing equation is very inadequate, in fact, incorrect, the complete correct equation being

$$2H_2 + O_2 = 2\,H_2O + 293{,}000 \text{ Joules}$$

This equation satisfies the law of conservation of mass plus energy, whereas the old one would not, because $2H_2O$ is a little lighter than $(2H_2 + O_2)$ at the same temperature.

But is the new equation really complete? The suggestion has been made that it is not, and that some day we shall add to the right-hand member of the equation a third term representing a mental factor:

$$2H_2 + O_2 \rightarrow 2H_2O + 293{,}000 \text{ J} + X$$

the X in this equation being the mind-stuff that is necessary to balance the equation.

Furthermore, it has been suggested that, just as the long-ignored energy term has come to be recognized as an important determiner of reactions, so in time we shall come to realize that the mental factor X is just as important as either one of the other two factors in determining the progress of a chemical reaction.

If that is true, one may wonder how we have been able to get along in chemistry so far without the X component. The answer is given that, just as the energy phenomenon is very intense and important in some reactions, and weak in others, so the mental element is imperceptible in inorganic reactions, very faint in germs, and very conspicuous in the brain. Also, just as the energy factor is never absent in a reaction, no matter how weak, so the mental stuff is never completely absent in the humblest reaction, down to the rusting of a nail.

If this view is true, we may well inquire also whether the law of conservation applies to the mental-stuff just as to matter and energy; and whether there is a conversion factor for the transformation of matter to mind-stuff and energy to mind-stuff, and vice versa, like Einstein's conversion factor for the transformation of matter into energy and of energy into matter.

This is a typical monistic philosophy. Its great merit lies in the fact that it unifies reality: instead of having three kinds of basic stuff—matter, energy, and mind—we have one basic reality, capable of assuming three different forms convertible into each other. A friend reviewing this manuscript remarked that perhaps the law of relativity holds also to the extent that what appears to one observer as mind may appear to others partially as energy and to still others partially as matter, depending on their coordinate systems!

The speculation is clever and intriguing, but it has its weaknesses. One of them is that, while it sounds like a scientific theory, it lacks scientific evidence. Another weakness of it is that, from a metaphysical point of view, it is naïve.

But what is metaphysics?

Just as modern physical science is a disciplined form of empirical knowledge, so mod-

ern metaphysics is a disciplined form of philosophic thought. Philosophic thought (of which metaphysics is a subdivision) is frequently referred to as "speculative" thought. That characterization was undoubtedly true about most of the pre-Kantian philosophic thought and is true also about a great deal of the modern, but philosophic thought does not necessarily have to be mere speculation. Kant asks in his *Critique of Pure Reason* if a *science* of metaphysics is not possible, and then proceeds to develop one—successfully, too, in the opinion of many qualified judges, for instance, Herbert Spencer, who incorporated a good deal of Kantian philosophy into his *First Principles.* Herbert Spencer's endorsement is particularly significant for us because he was a qualified scientist as well as a qualified philosopher—a rare combination. In the same sense in which we generally date modern science from the publication of Bacon's *Novum Organum* (1620), we may date modern metaphysics from the publication of this book of Immanuel Kant in 1781.

Well, what does this "science" of metaphysics concern itself with? What does it teach?

It concerns itself with a critical examination of the soundness of the foundations of the other sciences, with the truth—or reality, or meaning—of the data obtained by the scientific method. As to what it teaches, let us arrange an interview between Immanuel Kant and Albert A. Michelson—between one of the keenest philosophic thinkers and one of the ablest scientific experimenters—and see how their arguments might clarify this matter for us. Kant never traveled very far from his native city, so we may take Michelson to him on the occasion of a posthumous tour through Europe.

In Kant's Study

Michelson. Great privilege to meet you, Herr Professor. My associates in the psychology department tell me that you are the most profound philosopher.

Kant. I surely am pleased to meet a great physicist-astronomer. Your measurement of the diameter of Betelgeuse interested me a great deal. I am fond of astronomy, and you may be familiar with my nebular hypothesis. I have said more than once: "Two things fill me with awe: the starry heavens above and the moral law within."

M. You surely made a great hit with the astronomers with that saying of yours. It sounds like raising astronomy to the rank of the moral law. I wish somebody with prestige like yours had said something like that about physics—my real profession. I do not pretend to be an astronomer, even though I did make that measurement you mentioned. My most important work has been the determination of the velocity of the earth through the ether. The result has convulsed the scientific world. Einstein says it is the end of the Newtonian natural philosophy and the beginning of a new one he calls the Theory of Relativity. Of course, you are familiar with these developments. What do you think of them, Herr Professor?

K. I did see some reference to those things, but I must confess that I did not bother to look into the matter—I have so much to write. Furthermore, although I do not doubt the scientific significance of your measurements, yet I know "a priori" that they cannot have any philosophical-metaphysical significance whatever. The sciences are based on experiment, but philosophy—to be more specific, metaphysics, my specialty—cannot be based on experiment, nor can it be disproved by any set of experiments. Professionally, I am not interested in specific scientific theories (my interest in astronomy is only a matter of hobby).

I am interested in science, its foundations, the validity of its method, the possibility (or impossibility) of knowledge of reality, the meaning of the data of experience, the significance of moral law, immortality, the meaning of God, and like fundamental questions. I studied theology but soon discovered that its method—not necessarily its conclusions but its method—was very unsatisfactory, and so I developed my transcendental metaphysics.

M. Your comments intrigue me a great deal, Professor Kant. You say philosophy is not based on experience or experiment? Is it all rank speculation then? Any *knowledge,* to deserve the name, must be based on experiment and measurement: all else is fancy, if not folly.

K. Would you call mathematics fancy or folly? And yet it is not an experimental science. Euclid's theorem that the sum of the angles of a

triangle is 180 degrees is not based on mensuration, is it?

M. The way it is proven ordinarily, it is not; but if I were teaching geometry, I would get the pupils to cut out paper triangles, snip the corners and set them side by side to see that they add up to 180 degrees.

Kant smiles for the first time in his life.

K. My dear Professor, your pupils, as mathematicians, would make excellent experimental physicists like yourself. They surely would not add anything to our knowledge of mathematics and would ruin our confidence in mathematical generalizations. The most that can be proved about the angles of a triangle by physical measurement is that they add up to $180 \pm k\sigma$ degrees, σ being the standard deviation of the errors of measurement, and k a factor of conservatism based on the degree of probability we insist on. That kind of procedure could arouse a strong suspicion that the true answer is 180 degrees, but the suspicion would forever remain only a suspicion, never a certainty.

M. I think that it is the way it ought to be; there should always remain a little doubt or uncertainty. Newton gave the law of gravitation as $M'M''/D^2$ because various applications of the formula that he made agreed with it within the error of his data. But now, based on my interferometer tests, Mr. Einstein says that the true law is $(M'M''/D^2)\ (1+\varepsilon)$, ε being a very small fraction depending on certain things. If Newton had been more modest and had frankly kept in his formula the term of uncertainty of his data, he would have been considered a greater physicist today.

K. Professor Michelson, are you not mixing up physics and mathematics as if their methods were alike? The method of mathematical generalization is fundamentally different from that of the natural sciences, which fact makes one absolute, the other tentative. My nebular theory is surely tentative, subject to change in the light of more adequate data; but both mathematics and my transcendental philosophy are "apodictic" —not based on experiment and unshakable by any experiment.

M. All right, Professor Kant, I shall cite examples from mathematics to show you how some of these "apodictic" conclusions of mathematics have been proven to be wrong. A highly-esteemed associate of mine in our mathematics department was telling me recently that Euclid's axiom about parallel lines, as never intersecting, is not necessarily true; that the theorem about the angles of a triangle is not necessarily true; that even the axiom about the whole being greater than any of its parts is not necessarily true. I am sure the man is not crazy.

K. I shall take your word for your associate. What did he say *is* true?

M. He said that different kinds of space are possible, each with a different geometry, and he classified them as follows: (A) Real Spaces, including (a) flat, or Euclidean, space, (b) parabolic space, and (c) hyperbolic space; (B) Complex Spaces, including (a) one dimension imaginary, (b) two dimensions imaginary, and (c) three dimensions imaginary; and (C) N-dimensional Spaces.

Each one of the complex spaces and N-dimensional spaces also can be flat, parabolic, or hyperbolic. Einstein has hinted that our space is 4-dimensional, with time as one of the dimensions and imaginary at that. I must confess that I do not have the mathematical head to understand all these things, but I am inclined to accept the verdict of these geniuses as against Euclid.

K. Good. Did your friend say whether the geometries of these various kinds of spaces have been worked up at all?

M. Oh, yes. He said that each space is identified by a tensor K which represents the "curvature" of the space (don't ask me what that means); and if K is given, then they know the entire geometry of that space. He also showed me a book by Julian Coolidge entitled *Complex Geometry* in which one dimension is imaginary. It was full of theorems far above my head.

K. Were the theorems in that *Complex Geometry* proven experimentally?

M. Well, of course not. They were typical mathematical proofs.

K. Would you say that those theorems were provable by experiment, such as mensuration?

M. I suppose not, seeing that the space of that geometry was imaginary and not our kind: it had nothing to do with time.

K. You believe the theorems were true?

M. I am willing to give Julian Coolidge the benefit of the doubt.

K. Do you also believe that the geometrical theorems about those other kinds of spaces are true?

M. I am willing to take them on faith, because I do not understand them.

K. And they are not provable by experiment?

M. None, except those about our own real space.

K. I thought you were going to prove to me how experiment has overruled mathematical conclusions. Instead of doing that, you have told me how mathematics has progressed and how the recent mathematical generalizations have broadened the little field of geometry which Euclid had developed. You have done also something very significant for my philosophy and very damaging to your original thesis: you have admitted that it is possible to have "a priori" knowledge, that is, knowledge "before experience"—without experiment or observation—about spaces that do not even exist and which therefore could not possibly be objects of experience or experiment.

Metaphysics does not concern itself with specific scientific theorems. It is immaterial for my purpose whether the angles of a triangle add up to 179° or 180°, or 181°, or 180° + F(k): it is enough if the function F(k) is knowable without experiment. Metaphysics concerns itself with fundamental questions like these:

(a) Are there "a priori" judgments, that is, knowledge not dependent on experience for its truth (even though it may be occasioned by experience) and therefore not disprovable by experiment?

(b) How is such a thing possible?

(c) What implication does that have with regard to reality and God?

(d) How are freedom and moral responsibility possible in a world of physical necessity, and what significance does that have about reality, immortality, and God?

I have discussed the first three questions in detail in my book entitled *"Critique of Pure Reason,"* and the fourth in detail in *"Critique of Practical Reason."*

In the first book I have shown—but I should not bother you with these things, Professor Michelson, seeing you are on a vacation trip.

M. Do tell me about them, Professor Kant. You have aroused my interest, and you talk clearly and interestingly like a scientist, instead of enigmatically and oracularly like the rest of the philosophers.

K. Thank you, Professor Michelson.

All knowledge can be classified in two basic groups, namely, (a) "a priori," or non-experimental; and (b) "a posteriori," or experimental. Most of our knowledge is of course a mixture of the two.

Examples of the first are: Time has neither beginning nor end; space has no boundaries; all phenomena are the necessary consequences of the immediately preceding set of phenomena and the cause of the succeeding ones; all phenomena take place in space and time; the sum of the angles of every *rectilinear* triangle equals 180 degrees; those of a *curvilinear* triangle with curvature K, 180 degrees + F(K), the function F being as defined in the textbooks; etc. Note that these judgments need no experiment and cannot be disproved by experiment, that they are absolute and universal judgments, and that we cannot conceive of their opposites.

As examples of the second group: Today Professor Michelson visited Immanuel Kant; the diameter of Betelgeuse is so many miles; the wave-length of yellow light is 5800 Angstrom units, etc. Now, such judgments can be had only after the event, or by experiment; they are specific, not universal, judgments; and their opposites are equally conceivable. Am I clear and reasonable so far, Professor?

M. Yes.

K. Now, Professor Michelson, you remember Aaron's defense in the case of the golden calf. He said that people gave him their gold ornaments, he threw them into the fire, and out came a calf. Now I believe it is generally suspected that Aaron poured the molten gold into a mold; that, otherwise, he would not have gotten what he did. You agree with me?

M. Surely.

K. Let us consider the merits of conceiving of our minds as a highly complex and perfectly transparent and invisible mold into which experience throws a great miscellany of raw materials. In course of time, a miscellany of molded articles will be in evidence. Certain judgments about these articles will be really about the mold itself, while others will relate strictly to the raw materials.

The judgments about the *forms* will belong to the mold; and those about the *substance,* to the raw material. While our judgments about the substances can be only after the event and by observation, still, if the mold were conscious of itself as we are, it could tell with absolute cer-

tainty and universality, before the event, the alternative forms which any raw material thrown in will necessarily have to take, depending on the portal through which it enters the mold. Inasmuch as the forms in which the molded articles exist are the forms imposed on them by the mold, those forms are not the intrinsic properties of those materials in the mines, and the mold may never know the condition of the raw materials in the mines. Thus, much that it discovers by studying the molded articles will be information about its own self—what it does to the raw materials.

You see what I am driving at? Speaking figuratively, our perceptions, conceptions, etc., are all molded-and-assembled articles; our minds, the complex mold and assembly man. What we call knowledge or science is material automatically molded by the mind and set in a logical array. All of the universal elements in that exhibit are the properties of the mind itself, not of some other reality. The theorems about triangles and circles, about space and time, about causality, etc., are theorems about the "categories" of the mind. They are true or valid in the sense that they are the preconditions of what we call experience and knowledge. Any experience—for instance your interferometer measurements—are bound to take the forms that they do in the act of being observed, in the act of being calculated and reasoned. Thus it is that knowledge of non-existing non-Euclidean spaces is possible; for if something corresponding to them should come into existence and enter our experience, it would automatically and inexorably become cast by our minds, in the acts of observation, perception, and conception, into the very forms that the mathematicians of non-Euclidean geometries say our minds demand. You see, such knowledge is not really knowledge of a far-away fact, or of the future, but knowledge of our own mental makeup, knowledge of how we will react under certain circumstances.

Knowledge is necessarily something essentially mental. We grant that it is occasioned by the impact, on our minds, of a nonmental reality; but to identify the sound with the horn, the shadow with the man, the phenomena with the noumena (the reality-in-itself) is naïve. Knowledge of reality is not a duplicate of reality, but its token, and may not be any more like reality than a hundred-mark bill is like a hundred-mark gold piece of which it is a token. "The-thing-in-itself" is unknowable.

Does what I said make sense, Professor Michelson, or does it sound ridiculous to you?

M. Putting a reasonable interpretation on what you have said, I think I can agree with you, Professor Kant. Let me say it in my own words.

All knowledge can be divided into two classes: subjective and objective. We can dogmatize on subjective matters without physical experiment, but objective judgments must be based on observation of facts. Abstractions, like space and time, and the mathematical theories of the abstract spaces, are all subjective and therefore do not need experiment and perhaps may not be disproved by physical experiment. Color sensations and our feelings evoked by musical timbre are subjective qualities; however, they are evoked by objective facts which in themselves are harmonic phenomena in space and time. Matter is a substance—a reality-in-itself, a "noumenon," I believe you called it—and matter in space-and-time is a true objective fact, regardless of the presence or absence of an observer. And we may not know exactly what matter is. Is this not true? If not, what is the matter with it?

K. Phenomena can be distinguished as subjective and objective, but that distinction is not the same thing as that between phenomenon and noumenon. A subjective phenomenon can be true, and an objective phenomenon can be false or falsely evaluated. The metaphysical distinction is between appearance and reality-in-itself. I am talking about so-called objective facts. But the claim of an objective fact to identity with a reality-in-itself needs proof.

Every new glimpse of matter that we get turns out to be another *appearance,* and the reality-in-itself constantly eludes us. To be seen, reality must "appear" to us, and all that we can get out of an appearance is an appearance to which our perceptive faculties can respond.

A voltmeter either will not see a phenomenon we wish to observe, or if it does, it will measure it as a voltage! You can get an indication of temperature on a voltmeter, but this is made possible only when some provision is made to make the temperature appear like voltage to the voltmeter. The instrument may never know what it is that is being represented as a voltage! Let us consider your measurement of Betelgeuse. What did it look like in your interferometer?

M. I suppose you want me to say, "a series of light and dark bands of light," which it was, of course.

K. Precisely. To an interferometer, an object either does not exist, or exists as bands of light and darkness. To the ear a phenomenon either does not exist or exists as sound. But what you hear in the telephone is not the reality-in-the-wire: the receiver and the ear have modified it to make it perceivable by the mind.

In all detection and measurement by instruments, in all perception by the senses, the very act of perceiving includes as an essential operation the processing of the phenomenon into a form suitable for perception by the mind. The eye may tell the ear that what appeared to it as sound was really nothing but some undulations in air; and touch and taste and smell may say that there was nothing. The chief intelligence officer, studying these reports, may "reason" an explanation that reconciles these reports, but the *explanation* is only a system of percepts and concepts. Is the thing-in-itself a thought—something mental? Betelgeuse is an objective fact (as contrasted to subjective things), it is a *scientific* reality, but it is not that *philosophic* reality-in-itself that causes the senses and the reasoning to elaborate the scientific picture of it.

As a crude analogy, our minds may be thought of as a system of indicating instruments (perceptive faculties or senses) and integrating instruments (conceptive faculties). We may be sure of our indications and integrations, but never of the realities-in-themselves that occasion those indications and integrations.

M. We may admit that not all of our scientific theories and pictures are final truths, but is not at least some of our scientific knowledge the reality-in-itself, Professor?

K. What, for instance?

M. That the constellation of Orion is a system of particles arranged in the known fashion out in space, roughly so far away from us.

K. An essential element of that picture is space. If space is a reality-in-itself, independent of our perceptive faculties, what you say would be reasonable. But space is not the substance but the form of a percept. If space were an intrinsic property of reality, independent of perception, our knowledge of it would be exclusively "a posteriori," empirical; and then pure geometry would be impossible. But if space is a mental condition imposed on perceptions to make perception possible, then pure—non-experimental, "a priori"—geometry would be possible, as we believe it is. In that case, however, an object in space ceases to be a reality-in-itself and has to be rated merely as a *representation* of reality.

Science has an objective validity but only as a representation, nothing more; and the representation must never be confused with "the reality-in-itself." All discussions of reality have of necessity to be done in terms of words, in terms of thoughts; and thus, no matter how much we talk or reason, we miss the reality-in-itself, unless the latter is identical with the words or the thoughts.

Scientific reality is a construction—a projection—of the mind. Of course, it is not an illusion or fiction of the imagination, but neither is it the reality that the philosophically naïve believe it is.

M. Is not roundness an intrinsic property of the apple; or do we impose it on the apple?

K. That the apple shall appear to us as having *some* shape is imposed on the apple by the nature of our perceptive faculty; but that the apple should take *that* shape and not some other is the secret of the noumenon that underlies the perception of an apple. The noumenon is not something in space, inasmuch as space is a form of perception and conception; and, therefore, it is altogether futile to try to draw a one-to-one correspondence between the molecules of the apple and their noumena, and thus of the shape of the apple and that of the noumenon of the apple. Plurality, correspondence, etc., are mental concepts, and thus apply only to phenomena, not to noumena.

M. Professor Kant, what is the objection to saying that our mental pictures represent reality the way a paper photograph represents a person in the flesh?

K. Both the photograph and its object, being phenomena, can be subjected to identical scientific observation and their important correspondences and differences determined. But that cannot be done with our scientific picture of reality and the reality-in-itself. What if the correspondence should turn out to be like that of the musical composition, "The Blue Danube," to the Danube River? Undoubtedly, to the composer that music represented the river. Yet we would hardly accept a musical representation of a river to be of the same nature as that of a photograph and its

object. The scientific object we call river is in its turn a visual representation of a non-visual something which we may call X. The analogy is a very crude one, of course, and we must not push it too far.

M. Do you mean, Professor Kant, that the reality underlying the physical universe is not necessarily three-dimensional in itself, but that we see it so because our perceptive faculty is such; that it is perfectly possible that minds having a different perceptive faculty may see reality as four-dimensional or imaginary, or something else?

K. Precisely; and the multi-dimensional geometries tell us some of the relationships that we would discover among such perceptions if we had them. Our reasoning faculties are marvelous in so transcending our perceptive faculties. Our perceptive limitations are also necessarily those of our perceivable actions, and therefore we cannot circumvent nature or ourselves by an occult sojourn into the fourth dimension but must follow the three-dimensional scientific path to the mastery of phenomena.

M. I think you must concede that at least physical time is a reality independent of the observer. There must be a past, present, and future to noumena, just as much as to us, because the sequence of their action on our minds determines the sequence of the phenomena.

K. The bars of a symphony emanating from a phonograph have a time sequence to our ears, and yet our eyes tell us that the entire symphony, from the first bar to the last, exists on the record *simultaneously,* spread out in a geometrical pattern. Evidently, the perceptive faculty (the phonograph) converts the visual space sequence into an auditory time sequence. How can we know what it is in the noumena that our minds represent as a time sequence, seeing that noumena do not even have a space sequence in themselves? Furthermore, if time cannot be reversed, if the record cannot be played backward, the limitation might be inherent in the phonograph and not necessarily in the record or the noumena.

M. May I ask, Professor Kant, what conclusions you draw from all this about God Almighty?

K. God is a requirement of the mind—an "ideal" of the mind in my transcendental philosophy. A rational view of the universe without God in it is impossible. That, however, merely proves that the God so conceived of is a necessary condition of thinking and not necessarily the photographic image of something far away. As a reality-in-itself, God transcends scientific knowledge. Theologians sometimes speak of the Supreme Being as the First Cause, but that is very poor language; because as time has no beginning, there can be no first anything, and therefore no first cause either. Furthermore, a cause in a time sequence, no matter what its number, the first one just as much as the last one, would be only a phenomenon and therefore not God. God must be looked for in the realm of the spaceless and the timeless—the realm of the noumena—and *that* we cannot know.

M. Your philosophy is a bit discouraging, and, if you'll pardon me, a bit depressing to me, Professor Kant. It sounds like a philosophy of Can't.

K. Kant's philosophy is not all can't, even though there is a good deal of that in it. The positive aspects of it are sublime. However, we must first recognize the limitations of scientific knowledge, then we may the better evaluate the redeeming elements in my philosophy.

M. Do tell me something about those redeeming elements, Professor Kant.

K. Let me explain to you, then, the havoc that the English school of philosophers played with science and religion, and how my philosophy has saved both.

Imbued with the Baconian scientific spirit, and as a reaction from theological dogma, Locke scrutinized the facts of psychology the way scientists were scrutinizing the facts of physics, and in his *Essay on Human Understanding* he developed the thesis that all our knowledge comes from the senses in course of experience and that "there is nothing in the mind except what was first in the senses." At birth our minds are a blank sheet—a *tabula rasa*—and experience writes on it a host of facts through the senses. Sensations accumulate in memory, and memory begets ideas we call knowledge: we are not born with any innate ideas implanted in us by God as the theologians teach.

Then Bishop Berkeley developed the idea that the physical world is merely an appearance and that there is no matter or external reality corresponding to it.

Then David Hume, the brilliant skeptic, in his *Treatise on Human Nature,* picked up where Locke had left off and developed the doctrine that (a) all our scientific generalizations are in-

ferences from limited observations and therefore can never have an absolute validity. The only foundation for the belief in cause and effect is the observed uniformity in nature. Such limited observations, however, cannot prove definitely that the same cause must always have the same effect. (b) As to mathematical judgments, he taught that they are true only because they are tautological, that is, they affirm in the predicate what was already implied in the subject by definition; $2 \times 2 = 4$ is not new knowledge, but saying the same thing in two different ways.

With matter and its equivalent gone, with any dependable basis for scientific generalizations gone, and mathematics reduced to tautology, science was threatened to its foundations. That alarmed me and spurred me to philosophy. You see how my analysis saves science. The mind is not a passive tablet on which experience writes what it pleases. Matter, as we know it, is an appearance but not an apparition. Phenomena are molded by our perceptive faculties, and therefore experience cannot escape our perceptional forms. Scientific laws like cause-and-effect are relationships to which all phenomena become automatically subjected when they submit to observation by the mind. Knowledge is as much a product of the mind as of the noumena that act on the mind, and therefore the mind can lay down the law to phenomena in certain respects just as the noumena do in certain other respects. It is true that we are not born with knowledge of scientific generalizations and mathematical theorems: these develop as our nature in course of experience, just as a seed exposed to the soil and sun develops into plant and flower according to its own nature. But to say that there is nothing in the flower that was not first in the soil betrays abysmal ignorance of what the nature of the plant does to the material absorbed from the soil in which it grows.

The unsophisticated believe that one cannot abstract a rabbit from a hat unless there is one in there first. Well, there will be one in there first, if there is one in the sleeve of the magician first of all. Our minds are no mean magicians.

As to mathematics, it is not a matter of toying with definitions, but it is replete with *synthetic judgments*, with genuine new knowledge; and these have a controlling validity derived from the mind, in that no phenomena that submit to observation by the mind can escape the mathematical relationships required of them and imposed on them by the mind. If mathematics were nothing but playing with definitions, masters of language would make the best mathematicians. How contrary are the facts! A system of mathematics may be said to be implicit in its postulates but only in the sense that the latter define what portion of the vast field of mathematics may be considered consistently under a given title.

So much for what my philosophy has done to put science on an unassailable foundation in a new light. Let us review now what it has done for man's soul.

Just as the Bishop disposed of matter, so Hume disposed of the soul. To paraphrase him, he said: "I am aware of nothing but a succession of sensations. I find no mind except as the collection of this stream of sensations. I find no soul. These are theological dogmas with no foundation." So David (Hume) believed that he disposed of the theological Goliaths of freedom of the will, immortality, and God.

Before I indicate what my philosophy has done for the soul of man, will you tell me, Professor Michelson, how science solves the problem of the freedom of the will?

M. Science does not solve it. Physicists dodge it by confining themselves strictly to physics, and the other scientists avoid it the same way. Psychologists avoid it by dodging the physical aspect. If forced to face the issue, some scientists would say, "There is no freedom"; and others, including myself, would say, "We don't know."

K. Assume that science does not know it now; is it likely that it will ever know it?

M. I don't know. What do you think?

K. I don't have to conjecture about the matter. I know that science will never know it, because it cannot know it—with the methods it uses. Might as well hope to find iron filings with an electrified piece of amber, or lycopodium dust with a magnet. It is like trying to find God by going far enough back in time to catch the First Cause.

M. How does your transcendental philosophy solve the problem, Professor Kant?

K. This way. Space and time, and cause and effect, are mental forms imposed on phenomena; and, therefore, no phenomenon or datum of science, present or future, can escape physical necessity. What goes on in the brain, analyzed to the minutest detail, will be found to be the

effect of the preceding physicochemical state and the cause of the succeeding physicochemical state. The more minute the analysis, the more so will be the conclusion. You will never discover consciousness, moral freedom, etc., in the brain by studying it with an interferometer or any other scientific instrument or method, any more than you can discover what the musician calls "sound" by studying the vibrations in the air or the corresponding impulses in the auditory nerves. A person born deaf could become an acoustical physicist and yet never know sound. When you hear sound, you understand the musician.

Coming back to our problem, man has two aspects: one, as a phenomenon; the other, as a noumenon. As a phenomenon, he is bound to appear just as subject to cause and effect as any other phenomenon; but as a noumenon he is beyond the limitations that he himself imposes on phenomena. He is directly conscious of himself—something that could never be discovered by scientific observation in the absence of "apperception" (self-awareness in perception). Furthermore, when we say, "We should not do this; we ought to do that," it is the noumenon breaking through phenomena. We are then face to face with the reality-in-itself. The moral law exposes the artificiality of the pretty system that the cognitive faculties of the mind set up so as to make possible a scientific representation of reality and the physical mode of reaction to reality. All our actions, in so far as they enter the world of phenomena, observable by scientific methods, automatically become phenomena and stand in cause-and-effect relationships to other phenomena. That is their phenomenal-scientific aspect. But the conscience makes it clear to us that in their noumenal aspect our actions are free and spontaneous.

Physical necessity and moral or purposeful action are contradictory, but the contradiction is not an attribute of reality; it is what I call one of the "antinomies" to which the mind itself gives rise, and the solution of which is found in the mind itself—by a recognition of what the perceptive and cognitive faculties of the mind do to phenomena and how in moral action we get beyond them.

You can see why two things fill me with awe—the starry heavens above and the moral law within. In the cosmic spectacle, I am aware of one of the grandest products of the cognitive (scientific) faculties of the mind; in the moral law, the "categorical imperative" of the conscience—to act as if the maxim of our action were to become by our will a universal law of nature—I am aware of being face to face with that which transcends space and time—the ultimate, the self-sufficient, the Supreme Being. There is our clue to immortality. Immortality does not mean to live on and on in time; it means that, as noumena, we realize a nontemporal existence; it means passing from a scientific framework into a noumenal framework.

In the moral principle we have a glimpse of the noumenon that is ourselves in the most intimate sense. So, you see, my philosophy is not discouraging, but highly inspiring.

M. Professor Kant, I think I begin to get a little understanding of your transcendental philosophy, and I like it very much. I never heard anything like that before. If I may presume on your patience a little longer, I should like to say it in my own words, and have you correct me if I go wrong.

K. I will be highly pleased to see how far I succeeded in conveying my philosophic thoughts to a hard-headed experimental physicist.

M. The problem is how to reconcile physical necessity and moral or purposeful action. Also, how to reconcile physicochemical processes with intelligence.

When we consider what is going on in a head, if it is our head it looks to us like a pure mental process. We are aware of no brain, no matter, no physicochemical action, no cause and effect. If it is somebody else's head, it looks to us like a bony skull, containing a brain involving a highly complex organic chemistry, subject to cause and effect. Comparing the behavior of the owner of that head with our behavior, we may infer that the fellow must be intelligent like ourselves (though, of course, not necessarily to the same high degree), and that, like us, he must be aware of himself as a thinking, feeling person, not as a physicochemical system. We are likely to infer also that we must have a brain inside our skull and that our thinking process must be associated with it in some fashion.

That we are a thinking, feeling something is a matter of direct knowledge for us, while the idea that we have a brain and that our thinking is its function is scientific elaboration out of certain sense perceptions. Even if a surgeon should open

our skull and let us see our brain in the mirror, no amount of scientific study would enable us to recognize it as either ourselves or any of the thoughts that may be on our minds at the time. Granting that with sufficient study we should be able to determine with certainty definite correspondence between certain brain conditions and certain thoughts or emotions, that is far from finding thought or emotion in the brain. Correspondence would not mean identity. The more we study the brain process, the more bio-chemistry we shall discover, but we shall get no nearer to the discovery of thought and emotion by such a study—these must forever lie beyond detection by physicochemical methods. Not only that, but we may become increasingly convinced that the reactions going on in the brain are completely accountable by physicochemical forces, just as completely and inexorably as the rusting of a nail; and that, while we are aware of being conscious beings ourselves, it is scientifically possible (even though perhaps morally reprehensible) to treat others as absolute automatons.

We have inside information about ourselves as being intelligent agents whose behavior is purposeful action. Even when we are foolish, the intent is yet intelligent, and even when we accomplish the opposite of what we purposed, we still did act with a purpose; and it is enough for our present purpose that the behavior be of a conscious and purposeful nature, whether of a high or of a low order. However, looking at ourselves and our behavior through the eyes of outsiders, or through our own eyes but from the outside, we find that we are a complex system of organic chemicals capable of very intricate behavior, but still completely controlled by physicochemical forces, by cause and effect. There is the contradiction.

Which one shall we say is true?

We answer, "Both, from different points of view"; and having so answered, we are under obligation to reconcile the contradiction. The object of our study is something of which the internal aspect is that of an intelligent purposeful agent; the external aspect, that of something conditioned by physicochemical forces. Apparently, the progress of the changes in this reality can be traced equally well in either psychological terms or physicochemical terms. In practice, in some cases one is easier; in other cases, the other. For instance, theoretically the rusting of a nail could be treated in psychological terms, but perhaps we do not know yet how to do it in a worthwhile manner, and would prefer chemical terms. Also, theoretically, it is possible to describe the behavior of people—of ourselves—as those of a physicochemical system, but how hopeless in our present state of knowledge!

In the study of the living tissues, we find it necessary to carry along both views side by side and jump from one to the other as convenience demands. To study the human body in purely physicochemical terms, avoiding all reference to function and purpose, is a hopeless undertaking, just as hopeless as to study it as pure psychology, with no reference to the physics and chemistry of what is going on in the body.

The contradiction arises from, and is resolved in, the fact that reality has two aspects; an internal one and an external one. The internal aspect is that of an intelligent purposeful agent; the external one, that of a physicochemical system. Either view is theoretically workable to the exclusion of the other. They appear contradictory but really they are not; and that is the reason why it is possible in practice to carry along both views, applying one or the other as it may prove more convenient. Maybe someday we shall have the psychology of a rusting nail . . . and the chemistry of faith, hope, and charity. Because our knowledge is so incomplete—wholly external (scientific) of most things, and mostly internal (conscious) about ourselves—*the two views appear to us incompatible in the abstract and indispensable in the concrete.*

Professor Kant, we have a remarkable parallel to this in the present state of our knowledge of electrons.

Generally we treat the electrons as *particles,* having a certain mass and charge and subject to electrical forces and to elastic impact; but we find also that, in certain situations, an electron must be treated as if it were a *wave-train* of certain definite frequency, subject to the interference phenomena of waves, as opposed to the impact phenomena of elastic particles. Of course, it is puzzling now how an electron can be both a particle and a wave train at the same time, and, of course, we expect that this puzzle will be explainable in time; but whether explained or not, we are convinced now that certain concepts, like *particle* and *wave,* that formerly were considered as incompatible with each other and inapplicable

to one and the same thing, do apply to one and the same electron.

In our present state of knowledge, matter and physical necessity appear to us as incompatible with intelligence and purposeful action in one and the same thing, but if we are to accept the data of the physical sciences and of introspective psychology jointly, as the data of a philosophical system, then we must assume that the apparent incompatibility arises from the differences in the methods and points of view—one internal and direct, the other external and indirect—and that it remains for us to discover the code that will enable us to reconcile them and to translate one story into the other. I suppose someday a bright boy will discover the clue, maybe in the record of a Rosetta stone telling the same story word by word in both languages, that is, in both the language of matter and physical necessity and the language of intelligence and purposeful action; and, then, man, *that* will be a real "philosopher's stone." Eh, Professor Kant? Have I caught on to your transcendental philosophy?

K. You are doing pretty well, indeed, for the first lesson in metaphysics, Professor Michelson. May I make a suggestion? Someday when you put away the interferometer for good, and decide to go out in search of that philosopher's stone, look for it first in my two books. It is there. "My chief aim in this work has been thoroughness; and I make bold to say that there is not a single metaphysical problem that does not find its solution, or at least the key to its solution, here."

M. Professor Kant, you have so aroused my interest in philosophy that I am not going to wait that long to read your books. I shall have them with me on the steamer and shall incidentally test their efficacy in disposing of seasickness as a mere phenomenon!

Adieu, Professor Kant.

K. Adieu and bon voyage, Professor Michelson. *Auf baldiges Wiedersehen.*

STARLIGHT

The light from the stars not seen by the naked eye exceeds the light of all visible stars.—H. T. STETSON.

How bright the star-shine in this country place,
Above the topaz lanterns, moving, glowing,
That fireflies kindle over Queen Anne's Lace,
Whiting the field and hillside, billowing, blowing . . .
Here have I stood on a blue-white winter's night
When a thousand tiny prisms turned in the snow-drifts
And stars like ice shed blue and ruby light
In a jeweled revelation out of the cloud-rifts . . .
I have come here tonight with the world in the dark of the moon,
Brooding on sorrow, and desolate, near to despairing,
Weeping for soldiers, like rose-petals fallen too soon . . .
But the stars lean down; an astronomer's voice is declaring:
Oh, live not alone by the gleam of your finite discerning;
Through the spiraling stairways of heaven starlight is burning!

—BARBARA WHITNEY

AVIATION MEDICINE IN THE ARMY

By BRIGADIER GENERAL E. G. REINARTZ

RECENTLY while on an inspection trip, it was my pleasure to be interviewed by a feature writer of one of our prominent Northwest newspapers. When she was informed that I was a flight surgeon and an exponent of aviation medicine, she said, "Oh, that is a new type of medicine of which I know nothing. It must be a very new branch of medicine." When told that I, with others, had spent more than a quarter of a century in the practice of this "new type of medicine," she was covered with confusion. This is not an unusual situation, and only too few individuals know this rapidly developing field of specialized medicine. For specialized it certainly is as it deals exclusively with the individual who has learned that relatively new art and science—flying.

Aviation medicine had its earliest beginning with Leonardo da Vinci, the famous anatomist and first developer of the helicopter.

One hears but little concerning this subject until the Montgolfier brothers sent sheep and fowl into the air to determine whether or not any ill effects occurred to living tissue by reason of ascending into the atmosphere in a balloon. Nothing having happened, they then felt it was safe for human beings to ascend, and accordingly the first flight was made in October, 1783, by an individual who was surgeon, apothecary, and superintendent of the royal museum.

The first book containing scientific data on aeronautics was written by an American, Dr. John Jeffries, in 1786. These data were presented to the Royal Society on April 14, 1785, and read before it in January, 1786. Interestingly enough, John Jeffries on his second flight, that across the English Channel, was the carrier of an air mail letter, having delivered the same to Benjamin Franklin—"the first through the air."

The first handbook of aeronautics dealt in part with the physiological aspects of ballooning, and ascents were strongly advised for those convalescent from disease. The observation made at that time was: "The spirits are raised by the purity of the air and rest in cheerful composure. In an ascent all worries and disturbances disappear as if by magic." It was believed that this salutary effect was brought about by a change "from hot, putrid and impure to cool pure air; impregnated with the invigorating aerial acid."

In 1878, a most remarkable book was published by a Frenchman named Paul Bert. This book lay dormant for a number of years without its importance being realized. However, it has latterly been translated and has been given wide circulation because of its timeliness. The latter half of the book dealt, for the first time, with problems that are of vital importance in this age of stratosphere flying; namely, the effects of decreased barometric pressures and various phases of anoxemia.

Although the first heavier-than-air powered flight took place on December 17, 1903, the Wright brothers were discredited until 1908. Unfortunately, the importance of the conquering of this new element gradually dawned on other nations before it dawned on us. This is indicated by the fact that ten years after the discovery of heavier-than-air flight, our Government owned but two airplanes. The onset of World War I, from which we attempted so desperately to remain aloof, found us totally unprepared, and the land of the birth of the airplane entered the war "with an Air Service in its cradle and its aviation medicine in its swaddling clothes."

Dr. Theodore C. Lyster in 1914 appreciated the importance of temperamental, psychological, and physical qualifications for those who engaged in flying, and with others set up standards for the examination of flyers. This group laid the foundation of what is known as aviation medicine. General Lyster is therefore rightfully called the father of this important branch of medicine.

In October, 1917, the Medical Research Board and Medical Research Laboratory was formed and began to function. In January,

1918, the Central Medical Research Laboratory opened its doors. The work of the Laboratory increased greatly in amount as well as in importance, and rapid strides were made in the many problems with which this Laboratory was concerned.

The pioneers of aviation medicine during the last war worked on practically every problem with which we are faced today, at least to the extent of laying the basic foundation on which those of us coming after them could build. They worked on such problems as anoxia, effects of decreased barometric pressures, acceleration, and many other factors that were even then causing difficulties for the pilot although the airplane was in its operational infancy. One has but to read the literature of that period, meager though it is, to be convinced of these facts.

Those who founded the branch of science known as aviation medicine believed in the principle that those who were engaged in research should also be engaged in teaching. So it was that the School of Flight Surgeons was founded at Hazelhurst Field, Long Island, in 1919. It was also known to these founding fathers that the pilot in his newly found environment created an especial problem. This was all the more pointedly brought to their attention by the finding of the British that during the first year of World War I, 2 per cent of their losses were due to the enemy, 8 per cent to structural failure, and 90 per cent to the pilot himself and that after the institution of a service known as care of the flyer, their losses due to physical defects were reduced during the second year from 60 to 20 per cent and during the third year from 20 to 12 per cent. The comparable statistics of the present war cannot be stated for reasons of security.

The School has fostered research in aviation medicine through the years. Immediately after the last war, appropriations were drastically cut, medical personnel assigned to the Air Service was at a minimum, the research laboratory as such was closed in 1920, and yet the spark of research was kept glowing, albeit very dimly at times.

During the early twenties, the first satisfactory aerial ambulance plane was developed by a flight surgeon, Major Edward L. Napier, M.C. In 1926, one of the most outstanding and far-reaching developments in aviation was consummated; namely, the statement of the relationship between the illusions of the senses as developed in the internal ear and the fatal spin of the airplane. This development, the medical aspects of which were reported in 1936, was the result of research by a medical officer, the then Major D. A. Myers, M.C., and a pilot, the late Capt. William C. Ocker, A.C. The technical aspects were published in 1930. In my opinion this finding is the outstanding development in all of aviation, second only to that of flying itself. Prior to the announcement of this development, no long distance flights were possible unless conditions of external objective reference obtained. It was only after the theory of so-called "blind flight" was brought to the attention of those who had the courage to believe their bank and turn indicator instead of their intuitive sense in the "seat of their pants" that the extended flights of the present day, wind and weather to the contrary, notwithstanding, became possible. It was a heart-breaking experience to indoctrinate to mechanization those who believed themselves endowed with special powers that permitted them to fly without such newfangled devices as the bank and turn indicator.

During the late twenties, while assigned to the Matériel Division of the Air Corps at Dayton, Ohio, I began experimentation in a small way on problems involving the loss of hearing in flyers, the use of ear plugs, corrective goggles, the effect of noxious gases on the pilot, and the neuropsychic aspects of the effect of flight on flying personnel. I was followed by Major Malcolm C. Grow, M.C. (now Brigadier General) who developed the first medical research laboratory of the Air Corps and was its founder and first director. A tremendous stimulus was thus given to the advancement of medical science in connection with aviation. To General Grow must go the credit for stimulating medical research not only in the Air Service of the Army but also in other laboratories. The Aero Medical Laboratory at Wright Field has thus been the forerunner of research in this important field.

During this time the School of Aviation

Medicine was engrossed with training students to select and maintain flying personnel. Nevertheless, that staff too was not idle in research, and in 1934 Major (now Colonel) N. C. Mashburn, M.C., then Director of the Department of Psychology, developed the Mashburn Complex Coordinator, which with refinements is still the psychomotor testing apparatus that gives the highest validation in the psychomotor testing battery of the Psychological Testing Program of the Army Air Forces.

With the advent of the year of limited emergency announced by the President, Congress voted more funds for all purposes, and the research program of the Army Air Forces kept pace with the tremendous development begun by those forces. Highly technical personnel became available at the same time that new aeronautical medical problems were posed. The National Research Council with its Committee on Aviation Medicine became active, and laboratories all over our country were beginning to ask how they might assist in the solution of the many problems that were then presenting themselves.

It was about this time that the School of Aviation Medicine took on added growth, and the need was felt for a research laboratory to delve specifically into the problems of the individual himself. Thus it was that the Research Laboratory of the School of Aviation Medicine was activated January 20, 1942. There were then two medical laboratories in the Army Air Forces under the jurisdiction of the Air Surgeon. As has been stated, the Aero Medical Laboratory at Dayton, Ohio, had been carrying on the principal work and now with the development of the new laboratory at the School of Aviation Medicine some division of the responsibility had to be made. Thus the laboratory at the School of Aviation Medicine deals with the individual, his selection, his mental and physical body and its reactions to the varying conditions of flight, while the Aero Medical Laboratory deals with the things one hangs on that body, in other words, the pilot in his airplane plus all of his equipment.

It will neither be possible for me to relate the outstanding contributions to aviation medicine made by our sister service, the Navy, nor to go into the field of research so ably carried out by the many civilian agencies that are now spending much time and large sums of money on the most laudable solution of our many unanswered problems.

Since aerial warfare has become so devastating and the modern airplane flies at such unheard-of altitudes and speeds, many problems are posed at this time that were only of academic interest a few years ago.

War in the air was made less disastrous to operating personnel of aircraft by the development of the Grow "flak" suit, which has been markedly successful. This closely resembles the suit of mail worn as early as the fourth century and is donned as the combat crew prepares for its battle stations. It was simply the application of an old idea to the most modern of situations, with the saving of lives of many of our bomber personnel.

The increased range and accuracy of antiaircraft fire has forced the airplane ever higher, necessitating certain developments that would permit man to rise above this destructive force. During the last war airplanes would hardly rise to an altitude where life was actually jeopardized by lack of oxygen. Today, however, such flights are routine daily experiences. The oxygen mask with its many improvements is now a very satisfactory product delivering 100 per cent oxygen, if needed. Increased altitudes necessitated the development of the pressurized cabin. If the enemy should be able to reach our superfortresses and puncture the pressurized cabin, explosive decompression would result. To guard against that danger, pressure breathing of oxygen was also developed.

The increased speeds of airplanes with the accompanying development of tremendous "G" forces, plus and minus, have created problems the solution of which is sought by the use of the human centrifuge. These researches are leading to the production of devices that will minimize blackout and therefore make the pilot more efficient in his rapidly executed maneuvers.

The Army has developed low pressure tanks that can be refrigerated. It is possible in these tanks to reduce the pressure to a simulated altitude to which man has never

risen and to reduce the temperature to a degree never experienced by man in the normal environment. Extremely low temperatures, which are reached in the present-day bombing missions in certain types of our planes, have necessitated the development of electrically heated flying suits because the inherent warmth of the human body and the insulating effect of dead air spaces were insufficient to maintain comfort and efficiency.

Since in this war the pilots are engaged "around the clock," it became necessary to take into consideration the flyer's ability to engage the enemy at night. The testing of night vision was carried out, and an elaborate system of training in dark adaptation was evolved. We teach our personnel to view objects off center at night at low levels of brightness and to use a scanning or roving vision so that they may see the enemy better than they could by looking at him directly. This may be termed seeing out of the corners of your eyes.

Since much of this war is being fought in the Tropics, it has become necessary to know how the drugs used in combating tropical diseases affect the ability of the pilot to fly satisfactorily and whether they have any influence on his ability to tolerate altitude. It is also important to know whether there is any relation between altitude and recrudescence of the most prevalent tropical disease. With the tremendous upswing in global flying through areas that are heavily infested with insects that transmit tropical diseases, much concern is being shown by governments lest these diseases be transported either directly or by means of vectors. Disinsectization of all airplanes passing through or coming from such areas is mandatory.

Through the years we have been indoctrinated with the concept of physical exercise for the sake of physical fitness. As a result of wartime experimentation a new and unprecedented concept has evolved—physical exercise for convalescence's sake. When a patient who has been strong and physically well becomes a casualty, his excellent physical condition quickly retrogresses. It was thought that if exercise could be employed, reconditioning of the patient would progress much more rapidly. This has proved to be the case, especially where surgery is involved. The reconstruction program of the Air Surgeon permits men who become casualties to be rehabilitated more quickly, and it has the most far-reaching implications not only for the Army but for the civilian population as well.

In order to select the vast numbers of young men who must be trained to fly complicated and expensive airplanes, new methods of examining the prospective pilot had to be devised. The methods evolved have been eminently successful, and by far the greater proportion of those who pass the classification tests for flying become pilots. The results of these tests have validation by the pass-fail criterion in training only. Much study is now being devoted to the ultimate in military aeronautics—the question of pass-fail in combat. This brings to the foreground the will of a man to fight, the mental fortitude towards combat, the degree to which he has the killer instinct and whether or not his personality type is such as to make him flee or fight. It must be constantly kept in mind that no matter how well integrated an individual is mentally, each has his breaking point. When committed to combat, some break early, whereas others come through their battle experiences apparently unscathed. Each, however, carries with him some scars produced by the terrific emotional trauma experienced in modern aerial warfare. Much has been done and is being done to reduce the effects of these traumata. New methods of treatment have been evolved that permit the release of these emotional tensions with the result that the memory of the horrors of war is reduced to a minimum.

One of the outstanding contributions made recently in the interest of the safety of flying personnel has resulted from the study of the pathological lesions that develop as the result of rapidly applied decelerative forces when an airplane crash occurs. It has been found that typical lesions occur in the heart, great vessels, lungs, liver, spleen, and intestines. The new understanding of what happens to the human body in crashes may save many lives. Furthermore, changes in cockpit and airplane design are being made that will soften the blow of a crash.

With the tremendous increase in engine

noises and the whine of the tips of propeller blades that travel, in many instances, at speeds approaching that of sound, the assault on the pilot's ears is a matter of much concern. Added to this are the possibilities of the staccato insults due to machine gun and cannon fire, as well as the trauma produced by continual listening to the radio beam compounded by static that at times reaches such proportions as to approach the pain threshold. Much research is being performed in the solution of these problems, but success is somewhat difficult to attain, for as one reduces with ear defenders the trauma due to excessive noise, one also reduces the auditory acuity, with its attendant difficulties for the pilot.

Since time immemorial, individuals who have "gone down to the sea in ships" have become seasick. So also has illness overtaken many who travelled in trains and automobiles. With the advent of flying annoying airsickness made itself manifest. Investigations proved that many of these cases were based on factors with a psychogenic background; others have been caused by motion per se. At this time, the term 'motion sickness' is applied to those cases that have the characteristic symptoms of airsickness. Those who never become acclimatized in their new environment are therefore relieved from duty necessitating flying. It is interesting to note that individuals assigned to certain kinds of air activity are, as a class, more prone to motion sickness than are others. Considerable improvement through experimentation has been made which permits many who have been affected by motion sickness to become habituated to motion and progress to a normal, nonsymptomatic flying experience.

Flying all over the face of the globe, over all manner of terrain on aerial missions of hours' length, flying personnel are subjected to severe eyestrain due to the brightness of the sun per se, or to the reflected light from that surface of the globe over which they happen to be flying. This called for the development of devices to safeguard the most important sense organ necessary in flying—the eye. One need but visualize the actual pain developed by sun-searching for an enemy, the dazzling whiteness of the Arctic snows, the brilliance of reflection by miles of ocean, the searing glare of flying over tremendous stretches of desert, and the devastating effects of millions of candle power of searchlights to appreciate the devastating effect on vision and the absolute need for a device to protect it.

Protective goggles had to be developed and are used not only for the purposes mentioned but also to assist in the protection of flying personnel who may be subject to "flash" burns, due to the flash ignition of gasoline fumes released from gas lines severed in combat. Goggles, too, of varying shades of color are used by flying personnel in "ready rooms" in order to prepare themselves for dark adaptation so that their night vision will be most acute should they suddenly be called for a night mission. The varying conditions enumerated pose serious problems. However, their solution, while not yet adequately accomplished, is well on the way.

A final note must be added about the Army Air Forces School of Aviation Medicine. At this School, along with the experimental work that has been conducted, teaching of flight surgeons is its principal activity. Here medical officers of the Army Air Forces are indoctrinated in all matters affecting the pilot, the environment in which he works, and the vicissitudes of that environment. They are then sent to all parts of the globe where our airmen fly and are writing an ever-increasing, glorious page in the history of aviation medicine.

ON THE RELATION OF MATHEMATICS AND PHYSICS

By R. B. LINDSAY

It is reported that the greatest scientist who ever lived on this continent once remarked: "A mathematician may say anything he pleases, but a physicist must be at least partially sane." Most physicists and probably other scientists as well heartily agree with the first part of this dictum attributed to Willard Gibbs, but some of us are beginning to have our doubts about the second part. In these wartime days the word physicist is defined to mean a person who never gets a vacation, and few people bearing this title get even a moment or two to stop and think in the midst of their incessant preoccupation with the devising of bigger and better engines of destruction. And if we add to this group those who are busily engaged in instructing people how to use these engines of destruction, or teaching the fundamentals of physics to those who will ultimately have to use them (encountering in the process more than the normal "emotional resistance" to the subject), we may well wonder whether it is any longer fair to assume that physicists can remain even partially sane.

If this were a strictly logical presentation of the role of pure mathematics in physics, we should, of course, have to begin with *definitions:* "What is mathematics, what is physics, what is a relation, etc.?" There are numerous stunt definitions of these disciplines. From the eminent author of *Marriage and Morals* (and other somewhat more recondite works) we have long since learned that "pure mathematics is the class of all propositions of the form 'p implies q'." This means that mathematics is really symbolic logic, a subject already aptly described by another distinguished mathematician. Recall the famous dictum of Tweedledee in *Through the Looking Glass.* Said he to Alice in connection with some weighty mental matter: "Contrariwise, if it was so, it might be; and if it were so, it would be, but as it isn't, it ain't. That's logic." This remark about logic makes us the more ready to accept the even more notorious deliverance of the philosophical earl above quoted that "mathematics is the science in which we never know what we are talking about nor whether what we are saying is true." College students support this view wholeheartedly even when they do not understand its implications.

Just as familiar are the stunt definitions of physics, from the good old engineering version that "physics is the science of the ways of taking hold of things and pushing them" to the metaphysical cliché: "physics is only a state of mind." And speaking about metaphysics reminds us of the three-way comparison someone has made of philosophy, mathematics, and physics:

> Philosophy has been a human activity for ages, and philosophers have long sought to understand the universe. As a result of their efforts they have at length come to know almost *nothing* about *everything.* On the other hand, the mathematicians, who have been equally eager to understand, have through the course of the centuries achieved the proud position where they know almost *everything* about *nothing.* Finally the mere physicist, a modest and humble soul, having tried very hard, has at last been able to learn a little *something* about *something.*

This sort of thing could be continued indefinitely, but this is enough for our purpose.

To the average physicist the fondness for generalization suggested in the parable just quoted is undoubtedly the chief characteristic of the pure mathematician. To be sure the physicist considers *he* is working mathematically when to the accompaniment of much perspiration and some profanity he evaluates a certain infinite integral (usually approximately!) or solves a certain recalcitrant differential equation (also usually approximately!). But the pure mathematician assures him that all this is not really mathematics—it is merely manipulating symbols and is probably wrong anyway, certainly so if it fails to come within the range of the appropriate existence theorems. For

the pure mathematician is never interested in special cases unless they are strictly pathological. To him the proper aim of mathematical analysis is the establishment of the most general conclusion from the smallest number of restrictive hypotheses. Moreover, he refuses to permit any trace of uncertainty in the conclusions he draws; every element of his reasoning is scrutinized in the most severely critical manner, and anything that anyone else has to say about his reasoning is scrutinized with the same meticulous care. The results are open to the inspection of anyone who cares to examine a treatise on analysis. It will there be found that the pure mathematician would far rather say with absolute certainty something about continuous functions which are *not* differentiable than about functions which *are* differentiable. By the same token he feels even more pleasure in being able to say something about functions which are not even everywhere continuous.

This desire for maximum generality coupled with maximum rigor is very laudable. We certainly could stand a lot more application of the mathematician's ideal of rigorous, honest thinking in our daily lives and social relationships. Yet it cannot be denied that the emphasis on generality has, for the physicist, its inconvenient side. For it usually happens that the more general the theorem, the less it says which is useful to one interested in a specific application. Moreover, physicists are occasionally annoyed by the penchant of the mathematician for proving that under such and such conditions a solution of a certain equation exists without in the least indicating how to find it. But the latter is just the problem the physicist is worrying about. Actually he has little doubt about the existence of the solution: if the equation really represents a physical situation, there must be a solution.

But let us return to the question of the nature of mathematics, particularly in its relation to physics. It is appropriate to listen to what two distinguished physicists have said about it. In an address before the mathematical and physical section of the British Association at Liverpool in 1870, Clerk Maxwell made the following remarks:

> *As mathematicians* we perform *certain* mental operations on the symbols of number or of quantity and by proceeding step by step from more simple to more complex operations, we are enabled to express the same thing in many different forms. The equivalence of these different forms, though a necessary consequence of self-evident axioms, is not always to our minds self-evident, but the mathematician who by long practice has acquired a familiarity with many of these forms and has become expert in the processes which lead from one to another, can often transform a perplexing expression into another which explains its meaning in more intelligible language.

Maxwell then went on to state succinctly what we do as *physicists* in an attempted description of natural phenomena. In elaborating on the relation between the two forms of activity he finally comes to the part which appears particularly apropos of our present discussion. I quote again:

> There are men who, when any relation or law, however complex, is put before them in a symbolical form, can grasp its full meaning as a relation among abstract quantities. Such men sometimes treat with indifference the further statement that quantities actually exist in nature which fulfil this relation. The mental image of the concrete reality seems rather to disturb than to assist their contemplations.
>
> But the great majority of mankind are utterly unable, without long training, to retain in their minds the unembodied symbols of the pure mathematician, so that, if science is ever to become popular, and yet remain scientific, it must be by a profound study and a copious application of the mathematical classification of quantities which lies at the root of every truly scientific illustration.
>
> There are, as I have said, some minds which can go on contemplating with satisfaction pure quantities presented to the eye by symbols, and to the mind in a form which none but mathematicians can conceive.
>
> There are others who feel more enjoyment in following geometrical forms, which they draw on paper, or build in the empty space before them.
>
> Others again, are not content unless they can project their whole physical energies into the scene which they conjure up. They learn at what rate the planets rush through space, and they experience a delightful feeling of exhilaration. They calculate the forces with which the heavenly bodies pull at one another, and they feel their own muscles straining with the effort.
>
> To such men momentum, energy, mass are not mere abstract expressions of the results of scientific inquiry. They are words of power, which stir their souls like the memories of childhood.
>
> For the sake of persons of different types, scientific truth should be presented in different forms, and should be regarded as equally scientific, whether it appears in the robust form and the vivid colouring of a physical illustration, or in the tenuity and paleness of a symbolical expression.

So much for Maxwell! We are now ready for the opinion of the other physicist referred to above. The story goes that at a Yale faculty meeting at which the discussion grew long-winded (as it is apt to do on such occasions) on the comparative merits of courses in English, mathematics, modern languages, etc., the usually silent professor of mathematical physics finally rose and said with decided emphasis: "Mathematics *is* a language."

I have often wondered whether this is the basis on which students of mathematics in liberal arts colleges secure election to Phi Beta Kappa! I doubt whether Gibbs had this in mind, if he actually made this statement, which after all is merely an abbreviated form of Maxwell's comments. Mathematics *is* the language of physical science and certainly no more marvelous language was ever created by the mind of man.

In view of this it would certainly strike an ignorant bystander as paradoxical, or at least somewhat surprising, that the general public and indeed many physicists view with a mixture of suspicion and repugnance the increasing use of mathematics in physics. It is well known how difficult it is to make college students really use in elementary and intermediate college physics the mathematics they have learned in mathematics courses. A few years ago I thought it was possible to detect a trend toward the closer co-operation between elementary mathematics and physics, which would permit the early use of the calculus in physics teaching. This is not so clear today. The war situation should discourage hasty generalization, but I think we must reckon on the odd repugnance of the generality of mankind to deal with an abstract symbolism. This is a psychological problem of great interest though of great difficulty and one not within my competence. I am told by certain authorities that many persons are constitutionally unable to think mathematically, i.e., in terms of abstract symbols. This has always struck me as curious, for it seems to me that all persons who think logically at all are effectively thinking mathematically whether they are willing to admit it or not. The learning of a special symbolism is a mere device to facilitate logical thinking, and unwillingness to learn it probably reflects human inertia more than human incompetence. The equation of continuity of an incompressible fluid in the form $\nabla \cdot (\rho \mathbf{v}) = 0$ may leave the average citizen cold but he ought to be made to realize that he actually understands what it means if only he grasps the significance of that famous bar room which, I understand, exists in the city of San Francisco: it has two doors and whenever anyone enters one door, someone *has* to leave by the other. It is not at all a difficult concept to get hold of, viewed thus pictorially. Like the hero in Molière's play, who was astonished to find out that he had been talking prose all his life, many of our contemporaries would doubtless be amazed to learn of the amount of mathematics they really know!

Mathematics is a language marvelously adapted to the description of natural phenomena, but we must be careful to impress on everyone the necessity for understanding what the language says. Too many persons think of theoretical physics, for example, as mere juggling with symbols and symbolic relations. But the mathematical manipulation is meaningless without an understanding of the physical content. No matter how abstract a concept is, even if it is a quantum mechanical ψ function, a definite physical significance should be attached to the concept, which follows it wherever it wanders throughout the mathematical analysis. If we were more careful to follow this recipe we might prevent theoretical physics from becoming a mere meaningless algorithm for the prediction of the results of experiments. In this connection I like to recall what Maxwell had to say about Faraday in the preface to the first edition of the celebrated *Treatise on Electricity and Magnetism.* It will be remembered that he began the composition of his work with the supposition, common at that time, that there was a decided difference between Faraday's way of looking at electrical phenomena and that of the continental school of mathematicians. However, as he proceeded with his study of the *Experimental Researches in Electricity,* he became convinced that Faraday's method of description was also a mathematical one, even if not expressed in the conventional mathematical symbolism of the time. Actually

we now recognize that Faraday originated the field concept in electrical science and that Maxwell's great contribution was in translating Faraday's theory into the accepted mathematical notation of the nineteenth century. But the point for us to note is that in the use of his geometry of lines of force, Faraday reasoned mathematically in very decisive fashion. It is not at all unlikely that the more powerful modes of nonmetrical mathematical thinking typified by modern topology may ultimately find as useful an application to modern physics as Faraday's original geometrical notions.

We are all familiar with the fondness physicists display for analogies. They are used freely in teaching and in certain fields they have proved a powerful research tool. Think in this connection of the utility of electromechanical analogies in the field of communications. Their outstanding success has led to a peculiar situation: in order to explain to an electrical engineer, for example, how a mechanical filter works, it is necessary to replace the actual collection of masses and couplings by an equivalent set of inductances, capacitances, and resistances. Only then does he really understand it! Now the point about this which is relevant for our present purpose is that the successful use of the method of analogy depends solely on the mathematical equivalence of the schemes used to describe the phenomena in question. It takes little thought to see that such analogies never could have been developed from physical intuition based on observation alone. Certainly a cylindrical tube with alternate constrictions and expansions in its cross section bears no remote resemblance in its physical appearance to an iterated combination of coils of wire and condensers. It is only when we examine the two structures mathematically that we recognize that the tube behaves ideally with respect to acoustic wave transmission the same as the inductance-condenser structure with respect to electric wave transmission. Certainly there is a tremendous gain in the efficiency of our thinking in our recognition that both structures can be considered as energy-transmitting systems which are selective with respect to frequency.

The above illustration suggests the important role played in the progress of physical methodology by the choice of an appropriate notation which can be applied successfully to a wide diversity of phenomena. An example closely allied to what we have been discussing is found in the impedance notation for the ratio of a pressure analogue to a flow analogue. It is scarcely an exaggeration to say that this notion alone has opened the book of acoustics to electrical engineers who would have turned pale at the very mention of the name of Lord Rayleigh. It seems only fair to admit that it did not take the impedance notation to make the theory of acoustics clear to Lord Rayleigh; however, it certainly has made the use of acoustics much easier to hundreds of persons, and this is justification enough.

There is a converse to the picture. The mind of man is a strange thing; not content to economize by using the same mathematical notation to describe the most diverse phenomena, it feels that it gains a deeper insight into one particular section of experience by describing it with a wide variety of mathematical methods. A mathematics professor of mine many years ago used to say that it is much more illuminating to solve one problem by two or more different methods than any number of problems by the same method. It is hard to convince beginning college students of the validity of this point of view; they have apparently been too carefully conditioned against it by their secondary school education. But I think we must all admit that this is an idea which has led to tremendous strides in physics as well as in mathematics. Everyone knows that it is perfectly possible to develop the theory of elastic media in terms of sets of simultaneous equations connecting stress components with strain components. But think how much more insight is gained in these problems if we translate the results into tensor analysis notation! Maxwell stressed this point of view in his remark that "mathematics is the art of saying the same thing in many different ways." We must not be too much disturbed if the language tends to grow more abstract as this process evolves.

The reference to the word "art" in Maxwell's remark serves to remind us that much attention has been paid to this aspect of

mathematics as something created by the mind of man, possessing no necessary connection with his external environment and being in this sense akin to all other artistic creations, transcending common experience and common sense. What relation, if any, does this view have to physics? Certainly the study of history shows that early mathematics developed from the desire to describe nature more precisely than in terms of common language. Nearly all the early celebrated mathematicians were also natural philosophers. However, in more recent times, mathematicians have preferred to construct their abstractions without reference to the physical world and work with entities "that never were on land or sea." Physicists are apt to grow impatient with this sort of thing and label it mysticism or worse. It might be fairer if we compared it with music or art as an expression of man's emotions. G. H. Hardy in his recent book, *A Mathematician's Apology,* expresses openly the conviction that what he calls "real" mathematics must be justified as art if it can be justified at all—it has no other defense. Like poetry or music it promotes and sustains a lofty habit of mind. For one of the most enthusiastic panegyrics on mathematics from this standpoint I can recommend nothing better than the introduction to Lord Brougham's biographical sketch of D'Alembert. Brougham was an amateur mathematician along with his other versatile traits. Physicists may not like his treatment of Thomas Young and certainly he was pretty far wrong in his estimate of the wave theory of light, but we cannot help being impressed by the sonorous Victorian prose in which he emphasizes the depth of the pure mathematician's immersion in his subject, his attention abstracted from all lesser considerations, and his mind reflecting a calm and agreeable temper. The sublime effect is a bit weakened indeed when he solemnly asserts that "instances are well known of a habit of drinking being cured by the intensity of attention to mathematical researches." Moreover, we learn also that "an inveterate taste for gambling has been found to give way before the revival of an early love of analytical studies!"

On the whole, physicists should be glad that pure mathematicians exist and in fact ought to be willing to subsidize them if their limited means allowed. For it is becoming more and more clear that the pure mathematics of today will be the physics of tomorrow. This does not mean that the fertilization of mathematics by physics is over. On the contrary, the creation of new mathematical methods for the solution of physical problems proceeds at an accelerated pace. The vast amount of interest in operational methods initiated by Heaviside's operational calculus and the even newer work on nonlinear systems provide good illustrations. This is the field of mathematical physics—a genuine branch of mathematics, too often confused in popular parlance with theoretical physics, which is physics and not mathematics. If I may insert a parenthetical remark, it would be better not to use the terms mathematical physicist and theoretical physicist as synonyms—it is not wholly a trivial matter when it comes to placing people in jobs where they can do the most good.

It is becoming more keenly realized that mathematical physics is a more difficult field of endeavor than pure mathematics. For the pure mathematician creates his own problems, and if he strikes one he cannot solve, he usually manages to find another somewhat like it which he *can* solve. But the mathematical physicist has to take the problems which nature provides—he cannot dodge them. For this reason it is very important for the progress of physics that as many as possible of the best mathematical minds of the world shall devote their attention to mathematical physics. Under the impact of war this is taking place to a greater extent than ever before in this country. We may well hope that the process suffers no check!

As long as man retains his curiosity about his environment, he will try to describe nature, and as long as he expresses his interpretation in terms of relations among apparently diverse phenomena, he will continue to use mathematical reasoning; this will remain true whether we are concerned with metrical or nonmetrical aspects of experience. Of one thing we may be sure: physics without mathematics will forever be incomprehensible.

THIS BRAVE NEW WORLD AGAIN

By CHARLES F. MULLETT

AMID the prolific blue-printing of the "brave new world," education has been amazingly neglected. To this contention some will reply that I am overlooking the feverish, even frenetic, activity of reconstruction committees; but such groups, I am convinced, are considering means, not ends, and their policies will be at best trivial and at worst vicious in producing technicians, not educated people. The consequence will be to lay the groundwork of another national crisis and international catastrophe.

The record of the universities in wartime is indeed no cause for pride. Whether attention be directed to the eagerness with which administrators run off to their paltry gatherings or muddy the waters with their busy work; to the false promises made to prospective students (come and get anything you want); to the pathetic betrayal by scholars of their fields of knowledge either by sheer prostitution to practical ends or by pursuing with disgraceful haste every opportunity of getting their country to serve them and so finding a temporarily laudable excuse for leaving their obligations behind; or, finally, to the rewards out of all reason and justification that administrators have heaped upon men who have departed to do jobs that any WAC could perform much better—the story, I repeat, is a sorry one.

The professors who have remained at home have in many instances completed the picture by finding in the war an alibi for riding off in every direction except the narrow, hazardous path of scholarship. The university administration, following its orthodox creed of minimum efficiency, has further encouraged the degeneration of its intellectual tissue by devoting the major part of its facilities and thought to preparing to continue the same sort of half-education that the war has forced upon us—often without faculty protest—and by offering no adequate, let alone enthusiastic, support to its scholars.

In the midst of this shadow-boxing with problems already accepted as a *fait accompli* some few voices have been raised in criticism, and no doubt many obscure men have gone quietly and steadily about their business—the advancement of learning. These men, articulate or inarticulate, know that new departures, even ruthless departures, in procedure are necessary. At the same time they insist that before embracing the novel the universities must consider again and again the basic and eternal needs of man and the world. Such a scholar as Henry Sigerist, who has been pondering educational problems from many angles and for many years and who may be taken as the most outspoken apostle of the ideas herein set forth, has constantly pursued new methods and welcomed new views.[1] On the other hand and as constantly, he has not confused the path with the goal or techniques with education. His informed interest in both history and science has given him perspective and depth; his international contacts and social viewpoint have provided breadth.

With many thoughtful and sensitive men this philosopher has been deeply distressed over the cultural and intellectual blackout clouding the world since 1910. This era has destroyed both values and matériel. To offset the collapse of civilization—temporary though it be—culture in the old-fashioned sense is more necessary than ever. Its therapeutic virtue was demonstrated in the recovery of France after 1871 when Bernard and Pasteur, Flaubert and Zola, Saint-Saens and Frank, Cezanne and Renoir completely redressed the political humiliation. The German republic after 1918 showed many signs

[1] Mr. Sigerist has stated his position in the following articles from which any quotes in the present pages are taken: "War and Culture," *Bulletin of the History of Medicine*, XI (1942), 1–11; "American Spas in Historical Perspective," *Ibid.*, 133–47; "On the Threshold of Another Year of War," *Ibid.*, XIII (1943), 1–8; "The University's Dilemma," *Ibid.*, XIV (1943), 1–13; "The Study of Medicine in Wartime," *Ibid.*, XV (1944), 1–14; "The University at the Crossroads," *Ibid.*, 233–45. He is seriously considering bringing out these essays along with some others of the same sort, written or projected, in book form. The desirability of this is altogether obvious.

of recovery through its support of science, education, and diverse cultural enterprises. Conversely the collapse of France after 1918 may owe something to the cultural nihilism of Cocteau, Celine, and the innumerable "ists" who played with bits of things; and the suffocation of hopeful beginnings by the new barbarism may in large part explain the failure of republican Germany to realize its own renascence.

Superficially at least, not all cultural activities suffer from the war. Science, history, art, for example, enjoy wide support, but all too often their moral and intellectual values are submerged. In science, technology flourishes at the expense of understanding. To offset this the history, sociology, and philosophy of science must receive attention. The war makes demands and seems to offer great opportunities in such a field as medicine, yet there is greater need than ever to retain standards of research and clear appreciation of values in the face of emergencies.

In the historical field, propaganda, current events, and mere "background" have obviously all too often superseded history. Nevertheless,

> every situation we come to face, every problem that we are called upon to solve, are the results of historical development and trends. The way we act is largely determined by the picture we have of our past. Without sound knowledge of history we can act instinctively and opportunistically, but we cannot act intelligently. . . . The reconstruction of the world after the war will call for a mobilization of all resources of historical scholarship we possess, and it is therefore extremely important that the work that is going on at the moment be not interrupted. Studies that may seem far remote from the present problems may all of a sudden become of very acute interest.

If, moreover, we are to move from competition to co-operation and from technology to a broad social philosophy, attention to the social sciences, especially to law, is scarcely less important. Equally essential are cultural studies in institutions and in languages and literatures.

War is to society what illness is to the individual, not merely evidence of a collapse but, on the positive side, both an opportunity and a necessity to re-examine values. The makers of history are the philosophers (but lest some persons feel inclined to preen themselves, let it be remembered that I said *philosophers,* not grubbers on the surface of philosophic problems). Napoleon influenced history not as a soldier or even as an administrator, supreme though he was in both capacities, but as the personification of the ideas of the French Revolution. "The most formidable weapon the United States possesses in this war is not its Navy, not its Air Force or Army, but its Declaration of Independence and Bill of Rights." The philosopher is the nation's intellect. He alone enables mankind to keep abreast of the times by supplying honest, courageous self-criticism. Fascism regiments, we are all agreed; but are the artist and researcher in America truly free? "Is there not a regimentation of a more subtle kind, by the exigencies of the market?" Is there not a regimentation when gadget men of whatsoever sort in the universities get the largest salaries and the greatest consideration and respect from the administration, or when the supposed leader of scholarship, the graduate dean, openly expresses lack of sympathy with pure research and gives his support to "practical" items no matter how trivial?

Much is made of the necessity for eighteen workers in the rear to supply one man in the fighting line. This does *not* account for the scholar and the teacher, the poet and the artist. These needed men will determine whether the real victory is won. Nevertheless, one of the most hopeful features of the war era is that, for example, despite the accelerated and concentrated program in medicine, the courses in the History of Medicine at Johns Hopkins (all elective) drew more students in 1942 than ever before. Moreover, four medical students asked for a course in the philosophy of Plato, making it clear that they wanted not his science but his philosophy at large. This had never happened before. All over the country university men in the service have written back insisting on their profound realization of cultural values. These men have been tremendously stirred up by the war; they feel that they are in the midst of a gigantic historical process the nature of which they cannot define; they justly feel that historical and sociological analysis can help them to clarify their thought. If the university cannot help them, who can?

It is wrong for a university to fold up in time of war and turn into a mere technical institute. It must impart technical knowledge and skills, to be sure, hurriedly and concentratedly, but it must do it in the academic way. It is the method that makes it, and the personality of the teacher. Philosophy can be taught without special courses, in discussing the design of an airplane; instruction in sociology can be given while poison gases are being prepared. There is more philosophy, psychology, and sociology involved in every clinical case that turns up in the hospital than the specialists could dream of.

It is a truism that technology has everywhere outrun sociology; with all our means we cannot produce desirable ends (thus giving rise to the conviction that the means must justify the ends, rather than allowing the ends to justify the means). Destruction has outrun construction, yet if the war period last long, we must adjust ourselves to it as we adjusted ourselves to the economic depression. We must make decisions now and not postpone them, because "after the War" may actually be many years from now and it may then be too late. "We must not drop our cultural activities. In a total war they are a potential also and we may find it difficult to resume them later. Shostakovich's Seventh Symphony was a great Russian victory too." Myra Hess, giving noonday concerts of Bach and Beethoven in the midst of the Blitz, challenged Englishmen no less than Dunkirk, or "blood, sweat, and tears." At a time when Americans were cancelling all learned conventions, the hard-pressed Russians had time to hold large meetings commemorating the tercentenary of the birth of Newton.

Now that so many of us are in the armed forces, those of us who are left behind must work twice as hard as before, must give up every thought of comfort and readily accept living on a rapidly decreasing standard that will not soon rise again. There will be many casualties on the home front too because the human heart can stand only a certain amount of stress, but the readiness to sacrifice one's life for a just cause is not a privilege of the young people alone.

The war, of course, has opened many possibilities in education and science; the training in languages, technology, cosmopolitanism is bound to bear good fruit if the worms are checked in time. In particular the war may revolutionize medicine from a social viewpoint. Experience has more than once preceded science in medicine; and what is true there applies elsewhere. The possibilities for good, however, should not disguise the ready-made alibi which the war has supplied to the lazy, the superficial, and the downright mistaken. "Our universities will be facing an extremely critical situation which . . . is entirely independent from the war." Some years ago the ambitious young researcher wanted to become a full professor and head of his department so that he could guide it along the line of his ideals. This aim functioned well enough in the days of small departments. "It was often assumed and usually correctly, that a good researcher is a man who thinks clearly, and that a man who thinks clearly can express himself clearly and therefore must be a good teacher." Now universities are full of top-heavy departments and the chairman is an administrator who has no time for research. Yet if chairmen are administrators and not researchers, the university and the department will suffer, for "when practice is dissociated from research, it soon degenerates into mere routine."

Universities have often been slow to accept new circumstances, as they were in the fifteenth century and later, although Leyden and a few others quickly responded to the demands of the time. While the slowness is not an unmixed evil, it has often had the effect of driving out of the universities men and activities that might have remained to general advantage. Through the nineteenth century "students were instructed by men who were actively engaged in research and it was in the universities that the sciences took their great development." Now students receive instruction from men whose researches "ended the day they were appointed to some famous chair as a reward for outstanding researches" or from men whose researches stopped with their doctoral dissertation. If the universities continue to reward men only by making them administrators or by paying high salaries only to administrators (as is almost invariably the case), the scholar will seek other types of appointment. Thus if care be not taken, research will be divorced from the universities and seek refuge in private institutions ready to sponsor research and encourage original contributions to knowledge. Such a development might well prove fatal to humanistic

studies because the number of private institutions interested in these studies is pitifully small. Moreover, private institutions cannot in any case truly replace universities which without research will become mills imparting secondhand knowledge and offering only sterile education. The researcher needs students who will at once stimulate generalizations and force him to think through his problems clearly. Universities should create "distinguished" chairs for researchers in time to gain good from the holders and allow them to give a few, highly significant courses upon the essential content of which they have already spent untold hours and need only the opportunity and the stimulus to present what they alone know, to chart areas that they alone have explored; they should have time to give undivided attention to the larger aspects as well as to the minutiae of their investigations.

Every effort should be made to capitalize on the great tradition of learning, though this tradition may at times be a handicap as well as a stimulus; we need both a past and a future. Students in the midst of a tradition must realize their obligations and not coast on its reputation. There is always need for intellectual curiosity, critical judgment, imagination, proper values, social consciousness, correct English, and knowledge of working methods. These indeed constitute the best preparation for graduate study and are in a measure the vehicles of self-education.

In particular the duty of students is to become not merely good doctors, lawyers, merchants, but also good citizens. The lack of genuine education permits many physicians who are critical scientists in their own profession to "succumb to the most primitive type of propaganda and lose every critical sense as soon as social and economic issues are involved." Indeed any profession or vocation must be viewed "not as a technique but as a social function."

Such a view can only come when universities realize their proper place in society; and one of the chief ways is the advancement of learning. Yet they have so frequently operated on the law of minimum efficiency—getting the cheapest instructor and discouraging the only person who makes the university something other than a teacher's college or a vocational school. When the lack of students offered scholars the excellent opportunity to pursue their own investigations, many universities instead of taking advantage of that situation thrust their professors into army programs, the least rewarding instruction in many cases that ever man could offer. The demands were so tiring that research terminated, and in fact so great a fatigue, moral as well as physical, came over some men that they had not recovered for months afterward. Professors were, of course, in some measure to blame for their own predicament. Throughout the war they have in all too many instances eagerly dropped the work of a lifetime—the experience, knowledge, and interests of twenty years or more—to piddle. They have run off to Washington or anywhere else that would provide escape from the daily pursuit of learning. They wanted to contribute to the war effort, yes, but what a betrayal of learning that it became more important to engage in large-scale doodling than to advance the boundaries of their fields of knowledge.

The real scholar, taking the much harder way—doing his job as patiently and persistently as in the piping times of peace and order—knew that he must redouble his efforts even though, and here was his highest hurdle, he often doubted the value of his investigations. The ideas of an Elizabethan virtuoso, the career of an eighteenth century colonial agent, the legal status of religious minorities in England since the Reformation, the evolution of medical ideas, these seem so remote, so unrelated to the present crisis, so unimportant beside a "hush-hush" role in Washington. To make the matter worse, the university administration offers no leadership. How much we need presidents and deans who will lead, who, forbidding professors to piddle, will encourage scholars to continue those explorations where no one has ever gone, who will not surrender to every passing fad because it seems pertinent to the present crisis.

Treason to their responsibilities is, of course, the measure of the universities' failure. They are in the doldrums because their staffs are peeling potatoes, filing cards, and

teaching boys a modicum of information that bore the boys themselves. They are in a crisis because many professors believe that the ingenious devices for teaching army students will do for education, that a great gain will be accomplished if students can be run through in an ever shorter and shorter time. Universities and their staffs have forgotten that indoctrination, a smattering of techniques, a nodding acquaintance with superficial information is not education. They are in a crisis because they did not take advantage of the war's depletion of students to encourage scholars to do research instead of making more tools of research. They are in a crisis because they are no longer genuinely interested in learning.

Time and a proper intellectual metabolism are vastly more important than all the gadgets devised by curriculum builders. Not hours but time, not courses but work, a slow process of assimilation and maturation, these produce an educated man. Instead we face the plague of the half-educated, not merely for tomorrow but for years to come. Technicians we shall have in abundance and continue to have, but be it remembered that because there are few qualified young instructors today, ten years hence there will be few well-balanced, well-educated young professors. The professors in service have already lost touch with scholarship and with ideas; even if they come back with the intention of carrying on their researches, they may easily become discouraged or, what is even more vicious, they may be intoxicated with techniques or the "practical" nature of what they are doing. In either case intellectually they will offer nothing to genuine students. A man who has been forced by, or who has readily succumbed to, circumstances and has abandoned his laboratory or study for a number of years very rarely finds his way back to it. What is no less tragic is that the men who stayed on in the universities and kept learning alive may either be worn out or smothered under routine.

Yet, as has been remarked, the war only precipitated crises that were already apparent. Such disintegrating factors as lack of real encouragement to research—the amount of money spent by administrators gadding about the country would subsidize scholarship beyond the dreams of avarice—refusal to touch controversial subjects, the unhappy split between the "teacher" and "researcher," and the lack of intellectual leadership on the part of the university administration had been long at work. It cannot too often be insisted that "where there is no research there cannot be academic instruction" on a high plane, and if research is carried out of the universities, both they and research itself will suffer.

What must universities do to halt this disintegration and avoid their ultimate intellectual collapse? First, they must vastly extend their research activities and free scholars to do research, and I mean *research,* not gadgets. It is an inexcusable waste to have a man spend twenty or more years acquiring knowledge and experience in a field of learning and then compel him to spend his time teaching high school subjects, with which he is none too familiar, to freshmen, failing to do research because he cannot get a few dollars for travel, photostats, or typing assistance, and "discussing with committees whether a set of windows should have Venetian blinds or not."

Secondly, graduate instruction must not be allowed to become merely the imparting of technical knowledge: we must avoid that narrow specialization that makes a formula or bibliographical apparatus alone knowledge. The broader reaches of any subject under heaven can be intelligently discussed by intelligent people; and when the specialist resorts to jargon, he is proving his own lack of education and arousing suspicion as to the essential value of his subject, for it is notorious that the most specious subjects in the curriculum are most riddled with technical jargon and tools. The latest intricate device of International Business Machines is *not* an educated man; nor is a person spilling the formulae and barbarous lingo of his subject, for he is really little more than an animated (not much more animated and far less impressive and accurate at that) business machine himself.

Thirdly, undergraduate instruction must be solid. There can be no shortcuts, and the classics, the fundamentals, must get the attention. History, not Social Studies, must play a large role in this education: "a study

of contemporary life without historical and philosophic foundations remains by necessity superficial and meaningless." Let the pendulum swing back toward quality, and let the best, not the poorest, students set the pace. They crave something substantial, something fundamental, and they may help to educate their poorer brothers.

Finally, universities must remember that they are part of the world with responsibilities to perform. They should contribute to society, but their contribution must be their own, not that of the Rotary, the church, the home, the American Bar Association, or any old Marching and Chowder Club. Their contribution is knowledge, a constantly expanding knowledge substantiated by learning, refined by understanding, and directed toward the highest values. We must steadily realize that our actions are the instruments of our ideas and ideals and that they in turn are the products of our philosophy. Our philosophy is the result of our larger education, and the universities if they properly fulfil their function will, not merely by their instruction but also by their values, establish the quality of that education and hence of all the things that stem from it.

MEANS AND ENDS

Among the ancients spake the master Greek
Democritus, "the atoms move and change
The face of nature. Thus the new and strange
Springs from intrinsic laws which man may seek."

Augustine saw in fate the arbitrary rules
Imposed by God and subject to suspense;
To saints by revelation known, not sense
Nor gained by mankind's hard won mental tools.

Which view has brought us farther on the way
To the good life? Does either tell man where
To blaze his trail, for means are not the end?
Shall hedonistic impulse fill the day?
Shall we for mansions here or yon prepare?
Unto what goal shall we our best expend?

—JOHN G. SINCLAIR

LITERATURE AND SCIENCE: A STUDY IN CONFLICT

By CHARLES I. GLICKSBERG

THE conflict between literature and science, like the much more ancient one between science and religion, is still going on. Men of letters face the choice of becoming "slaves" of science (the strategy of submission) or remaining intransigent and independent (the strategy of revolt). The logic of events, the pressure of tradition, and a complex of professional motives have forced them to accept the gage of battle. Since they cannot resign themselves to the sovereignty of science, they must perforce revolt.

But what are they to revolt against? There is the rub. There is little agreement among literary men as to what they most object to in the scientific discipline. The warfare between literature and science turns into a war of scattered forces attacking irregularly on a wide, confused front. If the writers were clear in their mind as to what they were fighting *against* (they know what they are fighting *for*), there might be some hope of reconciliation or of waging war to a decisive issue. As it is we are left in a befuddled state.

What are some of the explicitly voiced objections against science? First of all, the scientific method is condemned on the ground that it is analytical and empirical; it is therefore fragmentary, not organic and universal. Second, it is concerned primarily with the realm of facts, not of values; it gathers data, it does not interpret and evaluate them. Third, instrumentalism may be a good laboratory technique; it is not a way of life. Fourth, literature differs in kind from science; it has its own laws and techniques; as an autonomous field of expression it is not susceptible of scientific analysis. Finally, the philosophy of science is squarely opposed to that of literary humanism.

The fatal weakness of those who attack scientists for their narrow vision and mistaken assumptions is that they themselves take a number of things for granted which are altogether dubious. By appealing directly to the innermost intuitions of the reader, they set up an untenable dichotomy between reason and intuition, head and heart. A refined sensibility, we are given to understand, is capable of a more profound apprehension of reality than the mind of the physicist—as if the scientist possessed no intuitions at all. Another and no less fatal error they commit is to assume a transcendental order of existence to which they, by virtue of their refined sensibility and clairvoyant intuitions, have special access. Fortified with such specious arguments, they call for a liquidation of our extraverted, mechanical, materialistic life and a return to the true inner self, a regeneration of the soul, a lifting of the individual from the naturalistic to the spiritual and creative level of the absolute.

All this sounds highly inspiring if one were only able to grasp concretely what is meant by these abstractions. The prestige of literature is at stake, and the litterateurs will not surrender without a desperate struggle. Why should "knowledge" be reserved for the scientific discipline, while literature—well, what does it do? It expresses emotions, it organizes attitudes, it communicates the wholeness and unique particularity of an experience, but it is not concerned with either knowledge or truth. It does not deal with ideas or their logical relationship or their empirical validity. Therefore, the defenders of literature hasten to demonstrate that literature utilizes a different linguistic function from that common to science, and that artistic truth is somehow superior to the truths of science.

Why so many writers and critics should feel a constitutional antipathy towards science is one of the mysteries psychology must explore, but this antipathy is at the root of the conflict that is still raging today. In the weather-beaten perspective of time, the result of this ideological struggle may prove as important in its effect on the course of civilization as the outcome of World War II. The litterateur, defending his profes-

sional interests, has become a forceful propagandist in a movement designed to undermine the validity of science. Even if the scientist wished to do so, he is not in a position to counteract this noisy stream of propaganda. His aim is to humanize and universalize the philosophy of science, to recommend the virtue of suspended judgment based on observation and critical reflection. He would extend the use of the method of empirical rationalism not only to specialized fields of investigation but also to the realm of politics, economics, ethics, social behavior.

It is indeed strange to find men of letters fulminating against science as if it were a fatally destructive Juggernaut, a Frankenstein. Both in England and the United States, the intellectuals give vent to hysterical squeaks of indignation at the rapid spread of scientific ideas. Some powerful emotional leaven must be at work to call forth this violent attitude of opposition, too irrational in substance to be explained on purely logical grounds. There is the shrill outcry that science spells the death of individuality. Impersonal, quantitative, precise, it would standardize not only commodities and methods of production but also men. It would reduce the world, "so various, so beautiful, so new," to a single, mechanical unit, whereas literature is based essentially on the qualitative principle. The creative life is concerned with values, tradition, ideals—elements which are alien and antipathetic to the scientific outlook.

Science, it is true, endeavors to arrive at objectivity in its observations and conclusions, thus tending as far as possible to eliminate the subjective, the bias of temperament, the fallibility that is human—all-too-human. Even if we grant this much, it is still difficult to understand why the writers are so envenomed in their protests. The argument directed against the mechanical aspects of science is a disingenuous rationalization. Something more fundamental is at stake: two world-attitudes are in conflict. If the truths of science prevail, and they are making irresistible headway on all fronts, then the pretensions of literature to a higher, unassailable, eternal truth must be abandoned. Some critics have stressed the idea that literature is the product of a mysterious, mystical intuition. Others have maintained that it is a criticism of life, concerned with moral values and with the projection of beauty otherwise unapprehended and unexpressed. It voices the universal through the medium of the particular; it affirms and gives imaginative life to the enduring faith by which men live. But if science strips off the veil of divinity from the ark of creation, if the sublime and universal truth of literature is shown to be neither sublime in origin nor objectively valid, if beauty and intuition are disintegrated by the ultraviolet rays of scientific analysis, then what is left for the writer? Literature becomes no more than a source of refreshment, a form of play, the sublimation of superfluous or frustrated energies. It can provide enjoyment and even illumination but not certitude.

Thus at the heart of this embattled controversy a fierce professional rivalry manifests itself. A rivalry perhaps unconscious in nature, but the writers who pitch angrily into science are, whether or not they realize it, defending their vested interests as purveyors of a "higher" truth. That is why they are in such a stew of revolt. In their wrathful desperation they seize upon any missile that lies ready to hand and fling it at the Mephistophelian head of Science, the dark angel destroying the religious sense and casting men adrift on a shoreless sea of doubt. The gods are unseated, and there is nothing to take their place. Man finds himself rootless, depersonalized, anarchic, in a universe of meaningless flux. Arbitrary and limited in outlook, science is considered guilty of a gross and inescapable narrowing of the field of vision. Inescapable because by definition it confines itself to conclusions only about those processes and events which can be known and verified. What do these objections amount to? Nothing more than this: Science is not religion, science is not mysticism, science is not prophecy, science is not art. But who ever said it was?

If literary men persist in their uncritical assaults on science, naïvely distorting the scientific outlook, if they continue to concern themselves with intuitions of a "higher"

truth, then the value of their work is bound to suffer. Science is no longer something external and abstract; it is an intimate part of the world we live in, already an integral part of ourselves, our perceptions, our thoughts, our cultural heritage, and to ignore it is a bit of inexcusable folly.

The attitude of the humanist scholar towards science is psychologically revealing. Three ways are open to him: first, he may reject the scientific discipline, exposing its limitations and contradictions; second, he may surrender his special privileges and accept the discoveries and doctrines of science; third, he may attempt a compromise whereby science is allotted its restricted sphere of influence while literature retains its own. The first method has been tried and resulted in conspicuous failure. The second solution of the problem was for a time highly popular. Since science had come to stay, was there any good reason why literary scholarship should not become "scientific"? Humanistic scholars would beat the scientists at their own game. Thus there was instituted the fetish of research, the religion of the authenticated literary fact, the mania of resurrecting forgotten texts and manuscripts. In the intoxication of engaging at last in "scientific" research, the work of interpretation and critical appraisal was forgotten.

But the scholars could not long fool themselves with the talisman of scientific research. This was getting them nowhere. What were they doing but turning out a race of glorified pedants, dry-as-dust scholars without taste, understanding, or critical appreciation. The method was supposed to be scientific, but the results were neither literature nor scholarship nor science. There was no high purpose, no unifying principle, behind these labors. Scholars had gone astray because they had, so they professed to believe, capitulated to the scientific discipline. It was, on the contrary, their lamentable misconception of the function of science, their crude failure to understand the nature and limitations of the scientific method, which had trapped them in this cul-de-sac.

If both methods had failed to work, the third was still available: a form of compromise. To each would be assigned a kingdom which it could govern: to science what belonged to science, to literature what was distinctively the province of letters. Thus the troubled waters were to be stilled. Unfortunately the truce was soon broken, for the simple reason that the literary scholars entertained a peculiar conception of the demesne they had been assigned to rule as their own. Science was arbitrarily cut off from the sphere of value, which then became a function exclusively reserved for the humanities. "Surely," Professor Norman Foerster declares in *Literary Scholarship*, "it is time for scholars in the humanities to make clear to themselves the fact that science is not the only respectable kind of inquiry." Now what can one mean by a "respectable" kind of inquiry? Even if we grant that literary scholarship must forge its own methods, why this emphatic repudiation of science? Why make the gratuitous assumption that values, which are the special concern of the humanities, lie outside the jurisdiction of science? Though more temperate in tone, Professor Foerster's attack is substantially like the one Irving Babbitt delivered in 1908 when he published his *Literature and the American Scholar*.

Only one conclusion is possible: men of letters, whatever the plausibility of the rational arguments they advance, are opposed to science because it destroys the picture of the universe in which they wish to believe. If the statements of science are true, then the as-if fictions of poetry must be discarded as sheer fantasy or make-believe. Yet there is no reason why the discoveries of science, once they are taken into the mental climate of the race, cannot, as William Wordsworth believed, become the nutriment on which poetry can feed. The advance of science does not sign the death-warrant of poetry. Whether or not he accepts the scientific outlook, the poet cannot sweat it out of his system. Whether he likes it or not, he inherits the culture of his age, and the culture of our time is predominantly scientific. There is not a major poet writing today whose work does not in some measure reveal the revolutionary impact of science on his thinking, his interpretation of the world, his

philosophy of values. The enforced isolation of science from traditional literary culture is an unsatisfactory state of affairs. A culture that deliberately divorces itself from the dominating ideas of its time dooms itself to pedantic futility.

The real issue at stake, then, is whether literary truth can be put into a separate category, entirely distinct from scientific truth. If literature presumes to communicate "truth," then this truth, no matter how derived or expressed, must compete on the same terms and in the same open market with scientific truths. There can be no exemptions, no dialectical distinctions. Either literature voices truth or it does not. If it does, then it must be prepared to meet the challenge of science.

In *The Nature of Literature,* another of the numerous attempts to explain literature in its relation to science, language, and human experience, Professor Thomas Clark Pollock contends that the function of science is to communicate referential meaning, while that of literature is to express and communicate the *wholeness* of experience, experience in all its immediacy and complexity, its aliveness and unabstractable realness. Once he accepts these limiting conditions, the scientist is neatly trapped. For "reality" cannot be defined or exhausted in referential terms. We get abstractions and generalizations, not the actual reality of human experience. Literature is presumably unique because it communicates the quality of experience, not abstractions from these experiences. In short, literary expression is alleged to be closer to the stuff of life, furnishing a more vital approximation to reality, than the abstractions of science. This theory leaves out the fact that the experience which it is the function of literature to communicate is also an abstraction: There is no correspondence, except a purely symbolic one, between experience and expression. A lyric kiss is but the fugitive shadow of a kiss.

This brings up the problem of truth in poetry, for poetic truth is a special instance of literary truth. Must emotions be forced into the channels of the reasonable and the valid, or can they lead a charmed life of their own, needing no excuse for being? There have been critics like Coleridge and I. A. Richards who argue that poetic beliefs have no connection at all with factual propositions. In *Communications,* Karl Britton concludes that:

> . . . imaginative writing has its quite distinctive "truth" and "falsity," its "reasonings" of the heart that Reason does not know; its "meaning." But for these different features of imaginative writing, the terminology of science and history is inappropriate and positively misleading. For the "truth" *that is peculiar to poetry*—its *validity*—is simply its value for men: this can be assessed, and statements *about* the value of poetry are themselves either true or false in the straightforward sense of these words. And the "reasons" of poetry are those emotional connections which are fundamental to poetry; they are not founded upon any relations of implication.

There is a flaw in this defence of poetry. If the "truths" peculiar to poetry are simply their value for men, apart from the rational-empirical truths of science, then the implication holds that poetry can entertain any truths at all so long as these are pleasing to the emotional needs of readers. Poetry therefore becomes a sublimation, a therapeutic, a land of make-believe, a blissful dream-world, a realm of delightful fictions. Such a defense draws a sharp line of cleavage between the truths of poetry and those of science. Actually no such cleavage exists. In their efforts to reach to the heart of Nature, many poets have turned eagerly to the scientific dispensation. When the poets of the Romantic school, led by Wordsworth, insisted that writers should keep their eye on the object and report truly what they beheld, they achieved a creative triumph of the scientific method. Wordsworth might ridicule the botanist who peeps and botanizes on his mother's grave, but he himself used his observation of plants and birds and natural scenery to excellent effect.

Exactly what science could do for poetry is a question that, until recently, had never been seriously asked. The problem, however, had not been correctly grasped. The question is not what science can do for the poet. For that matter, what can Nature do for the poet? It is not Nature, as Coleridge sadly realized, but the interpretation of Nature that counts supremely: what the

poets themselves as creative agents help to contribute. Similarly with science. If it has not exerted a fructifying influence on poetry, is the fault to be imputed to science or to the ignorance of poets, their adherence to convention, their subservience to tradition? Science has broken no promises for the simple reason that she has never made any. Science, like Nature, is there for the taking; those who have the eyes to see and the ears to hear as well as a generous share of imagination and talent, can fuse this rich diversity of new material into a brilliant creative synthesis. There is no warrant for the arbitrary dualism which sets science apart from literature, or which brings them into opposition.

The poet cannot turn to science in the expectation that it will solve his problems for him, but he cannot solve them himself without its aid. It can furnish him with a foundation of related and reliable knowledge, but it cannot supply him with talent and an integrated philosophy of life. It can point out the way of reaching truth, but he must walk the whole way himself. Science can teach him all that it has so far discovered concerning heredity, the influence of the cultural environment, the structure of the human personality, the psychology of instincts and emotions and thought, but it cannot make him feel this knowledge in his blood, assimilate it organically within his being. Ideas can be stated; they cannot be communicated. Hence if the poet is foolish enough to turn to science in the belief that it will give him a ready-made aesthetic philosophy, a definitive answer to all questions, a basis for the complete understanding of all problems, he is bound to be disappointed.

And there are a million and one things that a thorough knowledge of science will not do for the poet. Just as wide and varied experience and deep feeling will not necessarily make a poet, so training in the meaning and implications of the scientific method will not add one iota to the poet's talent or facilitate his mastery of form and technique. Skill in the handling of language, imaginative richness of texture, the evocation of mood, the wedding of sound and sense, the strong undercurrent of rhythm, these come as the result of training and practice and are not conditioned by the nature of the material at the poet's disposal. The linguistic medium is different in structure and aim from that of science.

But there is no escaping the impasse created by the allied problems of literary value and truth. If literature, as is confidently asserted, is the locus of value and gives expression to truth, these cannot, except in form, be distinctive and unique. The pluralistic assumption that there are all kinds of truth, with its corollary that literature yields a form of truth not only different from, but vastly superior to, the empirical truths of science, that is the assumption which has caused so much damage and confusion. The proposition is either true or false. Our contention is that it is totally false.

Poetry cannot presume to possess a validity that is superior to, or in conflict with, the findings of science, but there is no reason in the world why the poet, like the philosopher, who has mastered the scientific culture of his age should not know anything about life. In his iconoclastic book, *The Literary Mind,* Max Eastman had underlined this very point: that poets, as poets, do not know anything about life. Why should they "know" any less than Eastman, who is himself a poet? Is the mind of a Robinson Jeffers or Archibald MacLeish or W. H. Auden (to name but three significant contemporary poets at random) less richly endowed, less perceptive and understanding, than the mind of a psychologist or biologist? Poetry does not merely suggest the immediate quality of experience; it also passes judgment on that experience even if only by an emotional conclusion that it is good or bad.

No, science does not advance by driving poetry out. The advance of science simply imposes a greater intellectual responsibility on the poet. If poetry cannot in time assimilate the conclusions of science, it is doomed. True, it cannot feed on electrons and protons, on conditioned reflexes and the theory of relativity. Science universalizes the relations of things; literature clings to the individual experience. Exactly! Therefore there is no conflict between science and poetry. If the latter represents the world

as man discovers it, the representation must correspond in some measure to the comprehensive picture of reality furnished by science. For science too reports the world as man finds it.

Though poetry and science have different aims, they have much in common. Not that poetry, steeped in scientific lore, will degenerate into guides to conduct or that poets will fashion their work according to the latest bulletin from the laboratory or clinic. Spontaneity will have to remain, freedom of choice, genuine individuality of expression. Though the literary mind is heavily handicapped in an age of science, this handicap is its greatest promise of future achievement. In his *A Hope for Poetry,* C. Day Lewis declares that modern poets "are making strenuous attempts to tap the power of science by absorbing scientific data into their own work: by 'scientific data' I mean the myriad new sense-data which scientific development has put before us." For before scientific data can be rendered accessible to the poet, it must percolate through the general consciousness, become an integral part of the social environment.

From the time of Aristotle down, the critics have been laboring hard to make it out that literature, particularly poetry, was by some divinity of circumstance, some infusion of genius and inspiration, truer than history or science, a superior kind of revelation. Our object has been not so much to separate the two disciplines—literature and science—as to bring them fruitfully together. Each can profit from the other. Science can make the writer more scrupulous, more critical, more objective, less inclined to mistake the will-o'-the-wisps of the imagination for the truth of reality. It can bring him closer to the world of sense, enable him to realize the complexity of the universe, render him more humble and earnest in his search. In turn he must be willing to submit his conclusions to the empirical test, not to believe that his truths somehow partake of transcendental essences, that he portrays a "higher Reality." He must accept the responsibility imposed on one who ventures to make the truth of life known.

Once a writer accepts the scientific outlook, his isolation would end. Poets reared in the scientific discipline would discover that no disastrous consequences followed, that their will was still "free," that they still had an infinite variety of experiences to write about. It is not the function of the poet to interpret the conclusions of science in verse; he is not a popularizer of chemistry, physics, biology, and anthropology. What he draws on as relevant to his art and fruitful in its influence is the philosophy of science, the scientific synthesis. His task is to humanize science as it applies to the varied problems that man must face, the fate he must undergo on earth. He does not paraphrase the theory of relativity; he shows it in action in his poetic universe. He does not preach doctrines; he incarnates attitudes, beliefs, and these are strongly colored by the scientific outlook. Those poets who accept the philosophy of scientific humanism will abandon their futile war against science, convinced that science offers them a real and spacious world for the exercise of their talents and a rich soil for the use of their imagination and insight.

Literature can be restored to its high estate only on the condition that it renounce both the folly of laying claim to possessing a special and superior brand of truth and the even greater folly of denying that it has any concern at all with either knowledge or truth. Both philosophies are mistaken and self-defeating. For the sake of their own salvation, writers must reaffirm the vital and redeeming principle that literature, rooted in reality and born of experience, is essentially a criticism of life, and that this criticism will prove most efficacious when it works in alliance with the scientific outlook. Literature has everything to gain and nothing to lose from such an alliance.

AN ARABIC BLOCK PRINT

Very few people indeed, even among bibliographers of old books, are aware of the fact that the process of printing from carved wooden blocks, which the Chinese invented and Gutenberg developed into printing with movable type, had reached the Moslem world long before it was known to Europe, and was practiced in Egypt up to the middle of the fourteenth century. Although, as early as 1894, the Austrian scholar, Josef von Karabacek, signalized the existence of several examples of block prints in the Archduke Rainer collection of Arabic papyri, parchments, and papers (now in the Vienna National Library), his statement escaped the attention of the general public, and also of most specialists, until an American scholar, Thomas Francis Carver, assistant professor of Chinese in Columbia University, pointed out this impressive circumstance in his admirable book, *The Invention of Printing in China and Its Spreading Westward*, New York, 1925 (reprinted twice since the author's untimely death).

Carver, who was assisted in his inquiry by the outstanding authority on Arabic papyrology and book science, Professor Adolf Grohmann of the German University in Prague, emphasized the fact that, besides the block prints in Vienna (Karabacek listed only seventeen, but they are said to number about fifty) and in the Egyptian Library of Cairo (the number of which is unknown), very few specimens of these peculiar products of early printing have been preserved. Six in Heidelberg, one in Berlin, and two in the British Museum are known so far; possibly others may be buried among the miscellaneous items of other libraries and museums, still waiting for identification. As a matter of fact, only an experienced eye may be able to recognize them for what they are.

No wonder, therefore, that the unique example (unless others should be detected) of an Arabic block print in America lay hidden for over thirty years in the repositories of the Museum of the University of Pennsylvania without anybody noticing its extreme rarity. In a manuscript catalogue of the Arabic papyri, parchments, and papers in the Museum, most of which were purchased in 1910, No. E 16311 is listed as follows: "Vellum. Small Arabic amulet, written on one side. The first line, in a decorative panel, reads 'lâ ilâha illâ Allâh' [there is no god but God] followed by the formula 'bismi illâhi al-rahmâni al-rahîmi' [in the name of God, the Merciful, the Compassionate]."

It was only because the present writer, while going through the papyrus collection of the Museum, was reminded of what he had read in Karabacek and Carver, that he was able to recognize that that diminutive and

AN ARABIC BLOCK PRINT
OF THE FOURTEENTH CENTURY. UNIV. OF PA. MUSEUM

inconspicuous scrap of extra-thin parchment, not larger than two inches by one-and-a-half, was an invaluable specimen of block printing, the more precious inasmuch as all other examples, with a single exception in Heidelberg, are printed on paper, whereas the Philadelphia print is on parchment.

The Chinese method of printing from

wooden blocks never became popular among the Arabs. The cutting of the capricious curves of the Arabic script, where most characters are tied together as in our cursive script, out of a hard wooden surface proved too toilsome and the results too little attractive to meet the taste of a sophisticated public. Block printing was therefore confined to short and cheap texts, consisting either of selections from the Koran or of prayers, mostly used as charms and amulets; and of that kind are the contents of all known Arabic block prints.

The Philadelphia specimen is no exception. In its present state it is fragmentary. With a high degree of probability, it represents the uppermost part of a long and narrow scroll which was originally divided into several sections and has been cut immediately below the first: a minute part of the heading of the second section is still extant. Each section had a heading, written in ornamental Kufic script and surrounded by a decorative pattern. The heading of the first section, as stated above, reproduces the formula "There is no god but God" printed in white letters on a black background. Twelve lines follow, which contain the beginning of a prayer, introduced by a quotation from the Koran and consisting of pious ejaculations: "In the name of God, the Merciful, the Compassionate. God bears witness that there is no god but He, and the angels and those possessed of knowledge standing up for justice. There is no God but He, the Mighty, the Wise (Koran, 3:16). O Maker of everything which is made! . . . O Protector of every stranger! O Eternal without change! O Present never absent! O Winner never won! O Learned never taught! Thou art God who . . ."

The letters are extremely minute and since they were cut on a hard wood present an angular shape which lacks the slender elegance of Arabic calligraphy. Many of them, although differentiated in the regular script, appear here in the same shape, a shortcoming which increases the difficulty of reading the text.

As stated above, block printing appealed but little to the Arabs and was never widely spread there. After the middle of the fourteenth century its use was discontinued, and the very recollection of it vanished totally. The Philadelphia fragment apparently belongs to the latest products of that craft, the importance of which the Arabs failed to recognize as they failed to foresee the tremendous success which was reserved to it in the future. Actual printing with movable type entered the Arabian world at a much later date, and for two centuries after Gutenberg's first achievements Arabic printed books came out only from European presses, the oldest being a Christian Prayer Book printed in Italy in 1512.

In spite of this, or rather because of this, the few known examples of Arabic block prints rank with the rarest bibliographic treasures, and the tiny scrap of parchment in the Museum of the University of Pennsylvania may be of greater value than many a heavy block of carved stone preserved in its premises.—GIORGIO DELLA VIDA.

MINERALS, PLANTS, AND MEN

Lectures on the Inorganic Nutrition of Plants. D. R. Hoagland. 226 pp. Illus. 1944. $4.00. Chronica Botanica Co.

NOT in any sense an exhaustive monograph on the subject, this compact and readable book nevertheless succeeds admirably in focusing the reader's attention on a number of the more salient problems of the mineral nutrition of plants. The author's viewpoint is a broad one, but concision of presentation has been attained by basing most of the discussion on the data of a limited number of key investigations. Most of the material was originally presented as the Prather lectures of 1942 at Harvard University.

The subject matter is discussed in seven streamlined chapters, called "lectures." The first of these deals largely with the soil solution, the role of soil colloids, and other soil properties, and serves as an orientation for the following chapters. In the second lecture relations between the micronutrient elements and plant growth are considered, especial attention being given to the role of zinc. The following chapter is probably the best short summary now available of recent work on the mechanism of the absorption and accumulation of salts by plant cells, a line of investigation with which the author's name has long been associated.

In the fourth lecture the problems of the upward movement and distribution of inorganic solutes are discussed. Considerable attention is given to recent investigations in which radioactive isotopes have been employed in blazing the trail which mineral salts follow in their movements through the plant. The next chapter gives consideration to some of the problems of growing plants in artificial media such as sand and solution cultures. No attempt is made to discuss the details of these techniques but rather to give a general perspective of these methods as an experimental approach to problems of the mineral nutrition of plants.

In lecture six some of the biochemical problems associated with salt absorption are discussed. Emphasis is placed on possible relations between organic acid metabolism and protein metabolism on the one hand and salt absorption on the other. In the final lecture one of the essential plant elements—potassium—is singled out for detailed discussion. The problems of the soil-plant-atmosphere system, which repeat themselves according to a somewhat different pattern for each of the essential mineral elements, are illustrated in terms of this element.

Illustrative experimental material is drawn largely from the work of the author and other California workers. The book therefore serves the very useful purpose of epitomizing the important contributions to this branch of plant science by several groups of workers in that state in recent years. There are numerous figures, twenty-eight full-page plates, an author index, and a subject index. The binding and format are up to the general high standard of the monographs in this series. It is not a book that will stand idle on the shelf.—B. S. MEYER.

LOOK AT THE WORLD

Look at the World. Richard Edes Harrison. 67 pp. Illus. $3.50. 1944. Alfred A. Knopf, New York.

THE question of how best to portray the spherical surface of the earth on a flat map has taxed the ingenuity of cartographers for centuries. Distortion exists in all of the various types of projections, and in each type the pattern of distortion is different in character and amount from that of the others. We might draw an analogy by comparing photographs of a landscape which were taken from different viewpoints.

The average man's idea of what the world looks like has been derived almost entirely from one standard type of map—the conventional Mercator map of the world. In spite of its general acceptance, this map exaggerates the size of areas as we approach the Polar regions, and our ideas of the world are thus influenced largely by the fact that we always see it presented from this single viewpoint. A different perspective might result in a change in our ideas.

In *Look at the World,* Richard Edes Harrison gets away from the banality of basing all maps on the conventional Mercator pro-

jection and focuses attention on viewing the world from a number of entirely different perspectives. It is very interesting to study the geography of the world anew from such different angles.

Most of the maps in this atlas are on the orthographic projection, which approximates the view one gets when looking at a small globe, but other projections are also used. The cartography is excellent, and the atlas has been arranged in a most artistic and instructive manner. A gazetteer index in the back of the book enables one to locate unfamiliar places.

The author contends that the conventional showing of north at the top of the page prevents a flexible view of geography, and accordingly most of the maps are shown with north at various angles. This provides a new and interesting experience in studying maps from such points of view. However, some will still prefer north at the top of the page in order that they may more readily and more easily orient themselves as far as direction is concerned.

The author deserves credit for focusing attention on maps that do not follow the orthodox style but present the world from a different viewpoint. Only in this way will any progress be made.—G. S. BRYAN.

OLD ORAIBI

Old Oraibi, A Study of the Hopi Indians of Third Mesa. Mischa Titiev. 277 pp. Illus. 1944. $4.50. Peabody Museum of American Archaeology and Ethnology, Harvard University.

THE Hopi Indians of northeastern Arizona, because of their somewhat isolated location and a marked resistance to outside influences, have retained so much of their aboriginal culture that they furnish a fruitful field for ethnological investigations. These westernmost of the Pueblo peoples occupy towns situated on, or at the foot of, three mesas known as First, Second, and Third Mesa—as they are approached from the east—and one farming village 40 miles west of Third Mesa in the direction of the Grand Canyon. Dr. Titiev's main objective was a study of the Hopi of Third Mesa, their towns of Oraibi, Hotevilla, Bakavi, New Oraibi, and the distant farm colony of Moenkopi. Conditions at Third Mesa are particularly interesting because prior to 1906 Oraibi was the only town located there. The others were founded subsequent to that year by people from Oraibi. As a knowledge of the former populace of Oraibi is necessary to an understanding of all the villages, most of the investigations were carried on among its old inhabitants.

Dendrochronological evidence, the tree-ring calendar, shows that Oraibi was founded before 1150 A. D., and as it has been occupied continuously since that time, it is often referred to as the oldest inhabited community in the United States. From the coming of the Spaniards in 1540 until 1906 it was the largest and most important of the Hopi towns. Internal dissension and strife developing over a long period of years culminated in 1906 in the secession of about half the population and the establishment of Hotevilla on the mesa seven miles north of Oraibi. The next year Bakavi was founded on the mesa about a mile southeast of Hotevilla. In 1910 another exodus got under way, and New Oraibi at the foot of the southern end of the mesa was the result. Other groups have drifted westward to Moenkopi where, although still holding allegiance to Oraibi, they have settled permanently. In 1906 Oraibi had a population of over 600 living in some 150 households. Today it numbers about 100 occupying 25 houses. The remaining dwellings, through disrepair, are rapidly falling into ruin.

Dr. Titiev gathered all existing information about the social organization of Oraibi and in his report gives a full description of the manner in which it functioned prior to 1906. He also analyzes the factors leading to the split, discusses the dynamics of the disintegration of the town, and follows the elements of the population in their dispersal and founding of the new villages. The data on the social organization are complete and present a clear picture of that phase of Hopi culture. Discussions of the intricacies and significance of the kinship system and the reciprocal behavior of kindred unquestionably will appeal to ethnologists but may prove somewhat heavy going for the average reader. This is not the case, however, in the consideration of the amorphous Hopi state, the disintegration of Oraibi, and the sug-

gestions on the use of Oraibi ethnology in the interpretation of Pueblo archaeology.

The second part of the report relates to Hopi ceremonialism, the secret societies, cults, customs, rituals, and meaning of Hopi religion. The material presented is both informative and entertaining reading and gives insight into some aboriginal concepts of the origin and purpose of life and its continuity after death, of the nature and functions of the various gods, and of the significance of the rites performed in their honor. From his study Dr. Titiev concludes that the Hopi took whatever material measures they could to offset the dangers of crop failures, enemy attacks, devastating disease, internal dissensions, etc., and finding them an inadequate guarantee of the security they desired, they turned to the supernatural for assurance. In brief, the Hopi religious beliefs and practices were devised as a supernatural buttress for the weak points in the social organization.

Several aspects of Hopi culture that are only summarized in the discussions of the social organization and ceremonialism are presented in detail in a miscellany which comprises the third part of the report. In this way full information is made available without confusing the main trends of thought in the first two parts. In an appendix, constituting part four, are lists of the major ceremonies, names of chiefs, the ritual calendar, data on the ceremonial chambers and associated shrines, and other supplemental items. The report also contains a comprehensive bibliography and a topical index and glossary of native terms. No study was made of the linguistics, as other investigators are working on that problem.

Although basically an account of the culture as found at Oraibi, Dr. Titiev's monograph applies to Third Mesa in general and, on the strength of a comparative study, the Third Mesa situation may be regarded in the main as typical for all the Hopi. Specialists in the study of the American Indian will find much of value in it, and it will be particularly helpful to those primarily concerned with the aboriginal Southwest. The general reader can gain from it interesting information about one group of the Pueblo Indians.—FRANK H. H. ROBERTS, JR.

ROCKETS

Rockets, The Future of Travel Beyond the Stratosphere. Willy Ley. 287 pp. Illus. 1944. $3.50. The Viking Press.

THE present military use of rockets and jet-propelled planes and bombs has focused attention on them and has given rise to many misconceptions. *Rockets* is a book that will clear up these misconceptions and allow a much clearer picture of the potential and reasonable uses to which rockets may be put. Although written as a nontechnical book, a technical reader will find sufficient material to form a good starting point for further thought and calculations. The inclusion of some simple calculations (mostly in addenda) does not spoil the presentation for the layman.

The first half of the book presents an extensive historical background of astronomy and astronomical thought, as well as a history of rockets. This is done to show that although the past history of rockets has been a cyclic one, alternating between war and amusement uses, the future will see other and more useful applications. There are some very interesting facts about early use of war rockets. The perfection of rocket design accomplished by Congreve in the early 1800's will surprise most readers.

Since Mr. Ley was intimately connected with the VfR (German Rocket Society) from its inception, his detailed description of its work is quite complete and good. The diagrams and explanation of the devices developed are no less clear and lucid than his description of the way they behaved in experiments. His qualifications for writing this book extend even further than his personal contact with rocket research in view of the fact that he is a professional writer specializing in scientific history.

The description of the "Meteorological Rocket" is excellent. One would think it a description of an accomplished fact. It is convincing.

The oversimplification of the mathematics throughout the book is probably justified in view of its purpose. The discussion of orbits for interplanetary rocket travel will go a long way to clarify the problem. He presents a clear, coherent picture for the general reader. The explanation as to why

orbits should be used for all interplanetary travel is to the point.

The discussion of the subject of gravity is not so good, but it is short. On the other hand, the concept of a "Terminal in Space" is enticing. It is shown that the formation of an artificial satellite about 500 miles above the surface of the earth is a project that might be undertaken quite soon. It would be a rocket that would take up a permanent revolution around the earth and act as a laboratory, or even a point of departure for other and more distant travels. As a matter of fact, a proposition of three such satellites is developed in some detail. One is an inner one revolving around the earth in about an hour and three-quarters; another is about 3,000 miles up and completes a revolution in about three hours and twenty minutes; the third travels in an ellipse, acting as a transport between the other two. Although plans are set forth to man these satellites and construct rather elaborate facilities, one may suppose that a remote-control "automatic" laboratory would be a more attractive project for some time to come. Many interesting facts about the behavior of such a "space building" are brought out.

The mathematics given in the notes and addenda in the back of the book leave a lot to be desired. They should act as a stimulus for someone to straighten out and complete them. An elaborate bibliography covers more than one hundred references in English, German, French, and Russian on all aspects of the subject. Its inclusion indicates that Mr. Ley has read about all there is to read on the subject. He has written a good book.—H. C. VERNON.

NORTH AMERICAN WOLVES

The Wolves of North America. Stanley P. Young and Edward A. Goldman. 636 pp. Illus. 1944. $6.00. American Wildlife Institute.

THIS monograph, dealing with one of America's most picturesque wild mammals, is a fine example of what might be done with respect to many other members of our native fauna, especially those, like the wolf, that may be in danger of vanishing. The volume is a paragon of completeness and should be the standard work on these master carnivores for many years to come. Both authors are members of the Division of Wildlife Research of the U. S. Fish and Wildlife Service. They have clearly divided the authorship of their book, Mr. Young being responsible for Part I, on the wolf's "History, Life Habits, Economic Status, and Control," and Major Goldman for Part II, "Classification of Wolves." Mr. Young has had ample opportunity to observe wolves firsthand, having himself been once a predatory-animal hunter of the U. S. Biological Survey in the Southwest, later serving in charge of that bureau's Division of Predator and Rodent Control. Major Goldman is a veteran biologist—a specialist in mammalian taxonomy and ecology and in game management—and has explored more of the United States and Mexico biologically than probably any other living person.

Mr. Young's account is essentially documentary and represents years of digging into natural-history literature to exhume the record of the wolf's history. It is an attempt to collect all wolf lore and knowledge having any historical or scientific import. The author quotes copiously from the early naturalists, explorers, and pioneers, and it is evident that he has read virtually everything there is to read on wolves, past and present. (There are eighty pages of bibliography.) The result is a singularly exhaustive story, the sequence of presentation being as follows: Distribution of the wolf in North America; Habits and characteristics; Natural checks, parasites, and diseases; Economic status; Measures used in wolf capture and control; and History of wolf depredation and cooperative Federal wolf control. The wolf is described as symbolizing "power, ferocity, courage, fighting ability, and ruthlessness," and the biographer of the animal thus finds himself deploring those qualities that have made it a scourge to the stockman and an enemy of most other wildlife, while at the same time admiring the animal's nobler qualities and marveling at the firm place it has attained in legend, language, and literature. Mr. Young writes:

> From a biological as well as from an historical viewpoint, the wolves, linked with the dogs, are of surpassing interest as an outstanding group of predatory animals. In the more remote parts of North America, especially in Alaska, northern Canada, and on the other extreme, even in Mexico, suitable habitats remain where these large killers can exist in no direct contact with man. No reason is, therefore,

apparent to us why they should not always be tolerated, and even accorded a permanent place in the fauna of the continent; rigid control, however, must be maintained where their presence clashes with human welfare.

The history of the wolf, therefore, is mostly a story of man against wolf, with man now pretty much ahead in the conflict.

Major Goldman's section of the book constitutes a taxonomic revision of all the native North American forms of the genus *Canis* except the coyotes. His purpose is to dissolve the confusion that has long existed in wolf nomenclature, to provide a standard for identification, and "to afford a substantial foundation for the use of future workers in bringing together more comprehensive knowledge of the wolves of the world." He recognizes twenty-three subspecies of the gray wolf (*Canis lupus*) and three geographic races of the red wolf (*Canis niger*), describing his material as follows:

The revision is based mainly on a study of the extensive wolf material brought together especially in connection with the predatory animal control work conducted since 1915 by the Fish and Wildlife Service (formerly the Biological Survey), and other collections in the United States National Museum, now numbering 1,190 specimens. Many of these are skulls without skins, and in some cases skins without skulls. These specimens have been augmented by 178 from other American museums, making a total of 1,368 examined. The assemblage has included the type or topotypes of most of the described forms. This unparalleled wealth of material has afforded a basis for accurate appraisal of the range of individual and geographic variation, and has led to satisfactory conclusions in most cases.

Major Goldman's systematic account is accompanied by distribution maps and by tables of cranial measurements, which constitute one of the important characters in the group. There is also a complete "gallery" of skull photographs.

Mention should be made of the many excellent illustrations the book contains, particularly the six full-color plates from paintings by Walter A. Weber and Olaus J. Murie. These latter show especially the various color phases found in both the red and the gray species of wolves.

The book would have profited by a more diligent proofreading and by closer attention to some of the finer points of typography and bookmaking, but in general it is a distinct credit to both the authors and the publishers; and they may take pride in having provided so useful and worthy a contribution to our knowledge of the natural history of this continent.—PAUL H. OEHSER.

SCIENCE IN CALIFORNIA

Science in the University. Members of the Faculties of the University of California. 332 pp. Illus. 1944. $3.75. University of California Press.

ON the cover of the book it is stated by the editors that "This Volume is offered as a token of appreciation to the State of California and its citizens, who for three-quarters of a century have generously supported the University through the medium of public and private funds." The idea is so sound that one cannot help commending those who not only thought of it but actually saw it through. It is doubly gratifying to find that the attempt at informing the citizens of a state of the kind of research they are supporting has achieved the success to which the essays in this volume testify.

The book is not an effort to appease the public by giving it a glimpse of what is going on in one field of research or another; rather it constitutes a genuine and serious compilation of nineteen essays most of which are vibrant records of what scientific research involves and of the problems it faces and their relevance to knowledge and practice. No doubt the average reading and thinking citizen will find some essays more readable than others, but this is as it should be. The research fields of some of the faculty members are so specialized that the only useful function such scientists can perform is to summarize or review the background of their work. Others present their own work as well as the difficulties they confront and convey an intimate picture of the scientific quest for knowledge. Still others summarize their own researches in such organic fusion with the larger field as to present excellent accounts of both.

Of exceptional merit in this last group are the essay of J. H. Hildebrand on solubility, which is not only a model of lucidity and compactness but is also spiced with mellow philosophy, the essay by C. L. A. Schmidt on amino acids and proteins, C. B. Lipman's article on longevity, and D. R. Hoagland's on plant nutrition. Of equally high merit both for readability, scope, and content and

for interest to the general reader besides, are the contributions by J. R. Oppenheimer, C. E. ZoBell, R. W. Chaney, L. Miller, J. M. D. Olmsted, Knight Dunlap, and S. J. Holmes. These essays are by no means stereotyped reviews. Each is replete with original and stimulating ideas which make the material both uniquely interesting and informative.

Of special interest are the series of articles dealing with geological and meteorological aspects of the California Coast. This local color adds much to the glamor and logic of the book since it is but fitting that a University pay some attention to local needs and local features. Somewhat in a class by itself is the article by R. B. Goldschmidt which discusses a difficult and specialized problem concerning the nature of the gene. It is an illuminating and stimulating essay, conveying the difficulties confronted in laying the foundations for a basic theory in science.

The other essays in the volume are equally rich and lively. All nineteen contribute to make the volume a true cross section of University research in modern times and of methods in the presentation of material. This is not a plain-talk report to the average citizen; rather is it a report to the citizen who has considerable familiarity with the broader outlines and problems of science. It is a pioneering start, and a venturesome university might even try in the future the kind of report that can actually reach every member of the public.—MARK GRAUBARD.

THE PASSING OF THE EUROPEAN AGE

The Passing of the European Age. Eric Fischer. 214 pp. 1943. $2.50. Harvard University Press.

IN this philosophical book the author presents the theory that the civilization of our present-day world had its origin in Europe, that the seeds of that European civilization have been transplanted into all the other continents where they flourished, took on color from the new environment, and matured into a new cultural entity. During its day Europe not only supplied the seeds of the most aggressive world civilization but at the same time dominated that civilization in all parts of the world. It maintained an essentially European age.

As the seedlings of transplanted European culture matured in distant lands, they all followed rather similar patterns of growth. First, they established the cultural practices and national traditions of their particular homelands in a new and foreign environment. Then followed a period of selection during which the good importations were preserved, the bad ones eliminated, the indifferent ones tolerated, and new adaptations developed to fill gaps in the inherited body of cultural equipment. As changes occurred and became well established, the new lands developed national consciousness of themselves and in many cases openly broke with the mother country, as did the United States with England and the Latin American countries with Spain and Portugal. In other cases the break was less violent but nevertheless effective, as the British Dominions with their mother country.

In the next stage in this evolution the transplanted cultures began to dominate and began to throw seeds of their own propagation back to the parent land. That is the stage in which we stand today, according to Dr. Fischer, and the stage that justifies the title of his book.

This book is an optimistic treatment of a subject and process that Spangler and others have considered with considerable pessimism and gloom. Dr. Fischer sees, not the passing of European, or Western, civilization, but rather the passing of an age during which Europe dominated most of Western culture. His is a theme of hope for the future, a future of balanced cultural forces in which peace can be achieved.

The Passing of the European Age is stimulating reading. The author supports his thesis with numerous examples drawn from all parts of the world. Since it is a philosophical treatment of the subject, the illustrations are qualitative rather than quantitative. They leave us at a point of departure from which we should like to proceed into a more detailed analysis of the subject. But, though brief, the book is well worth reading for its optimistic and hopeful attitudes concerning our changing, growing Western civilization.—A. K. BOTTS.

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